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REPORTS OF THE SWEDISH DEEP-SEA EXPEDITION 1947—1948

EDITED BY

HANS PETTERSSON

SCIENTIFIC LEADER OF THE EXPEDITION

VOLUME I

The Ship, its Equipment, and the Voyage

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CONTENTS - Vol. 1.

Page

1. Pettersson, Hans: The Voyage 1

2. Christiansson, E. Th.: How the "Albatross" became a Research Vessel 125

3. Jerlov, N. G., Koczy, F., Kullenberg, B., and Michaelson, R.: Winches and Laboratories 143

Vol. 2 Contents →

Vol. 3 Contents →

REPORTS OF THE SWEDISH DEEP-SEA EXPEDITION. VOL. I
THE SHIP, ITS EQUIPMENT, AND THE VOYAGE. NO. 1

THE VOYAGE

BY

HANS PETTERSSON

Contents

Page

Historical and Organization of the Expedition 4
Historical 4
Modern Deep-Sea Expeditions 7
Swedish Oceanographic Research in the XX:th Century 9
The Origin of the Swedish Deep-Sea Expedition 11
The Test Cruise with the »Skagerak» 18
The Ways and Means 22
Planning a Circumnavigating Cruise 24

The Atlantic Ocean I 29
The Start 29
From Leixoes to Funchal 31
From Madeira to Martinique 33
From Fort de France to Christobal 38
From Christobal to Balboa 42

The Pacific Ocean and the Sunda Archipelago 43
Panama — Galapagos 43
The Galapagos Islands 46
Galapagos to Nukuhiva 48
Nukuhiva and Tahiti 53
From Nukuhiva to Tahiti 55
Tahiti 56
From Tahiti to Hawaii 57
Honolulu and the Hawaiian Islands 63
Honolulu to Ternate 65
The Kapingamarangi Atoll 67
Kapingamarangi to Ternate 68
Ternate and the Sunda Archipelago 70
Surabaya and Java 72

The Indian Ocean 72
From Java to Ceylon 72
From Colombo to Port Victoria 76
The Seychelles 77
From Port Victoria to Suez 79

The Mediterranean 81
From Suez to the Strait of Messina 81
The Strait of Messina to Monaco 86
Days in Monaco 87

Page

The Atlantic Ocean II 88
From Monaco to the Cape Verde Islands 88
From the Cape Verde Islands to the Romanche Deep 92
The Romanche Deep 93
From the Romanche Deep to St Paul's Rocks 99
St Paul's Rocks 100
From St Paul's Rocks to the Virgin Islands 102
The Virgin Islands 104
From the Virgin Islands to London 105
With the »Albatross» to London and to Göteborg 109

The Harvest from the Ocean Depths 111

References 114

Historical and Organization of the Expedition

Historical

Deep sea research is as yet not much over a hundred years old. In the middle of the XIX:th century the pioneer investigations by EDWARD FORBES of the marine fauna in the Aegean Sea, a repetition of the classical studies, made there by ARISTOTLE 22 centuries earlier, had attracted the attention of marine biologists to the problems of the deep.

From the rapid attenuation in the number of marine organisms with increasing depth FORBES inferred, that beneath a depth of 300 fathoms the sea is uninhabited, an azoic region, devoid of life. The dogma FORBES put forward of a »zero-line» of organic life in the sea at 300 fathoms, was accepted by most of his contemporaries. But it was strongly disputed by certain investigators, especially in Great Britain and in the Scandinavian countries. By means of dredges and traps they had found that abundant life exists also in depths considerably greater than FORBES' 300 fathoms.

In fact decisive proof of the existence of abysmal life had been produced already in 1841 by Sir JAMES CLARK ROSS. During the British Antarctic Expedition (1839—43) he brought up beautiful specimens of coral, corallines, flustrae and other invertebrate animals from a depth of 400 fathoms. But these important finds were for many years ignored by most scientists.

In 1860 a telegraph cable laid across the bed of the Mediterranean gave way at a depth of 1 200 fathoms. When raised for repair corals were found to grow on the cable where it had ruptured. In somewhat lesser depths molluscs, worms, bryozoa and specimens of other, higher groups of animals were also found attached.

During the third quarter of the XIX:th century a number of deep-sea cruises were sent out from different countries, partly for bathymetrical purposes in preparation of the laying out of submarine telegraph cables, partly for collecting deep-sea organisms. These efforts at deep-sea research culminated with the famous circumnavigating cruise of H M S »Challenger», 1872—76. Sent out by the British Admiralty and the Royal Society of London conjointly, this excellently equipped and carefully organized expedition during 29 months cruised through the three oceans, as far south as to near the border of the Antarctic ice. Studies were made of the temperature, the salinity, the oxygen content and the plankton present in different water-layers. Samples from previously unknown deep-sea deposits, i. a. from the typical abyssal sediment, the

red clay, were raised and studied. In addition meteorological, magnetic and current-observations were made and representative collections of both pelagic and bottom-living fishes and invertebrate organisms were obtained. The results from this pioneer work were published in over 40 large, beautifully illustrated quarto volumes. The »Challenger Reports» have justly been called: the »Holy Writ of deep-sea research.»[1])

Fig. 1. H. M. S. Challenger.

In the following decades a number of other deep-sea expeditions were sent out from the United States, from Germany, Norway, France Russia, Italy and Austria. Of special interest were the cruises into the Mediterranean and the North Atlantic, organized and commanded by PRINCE ALBERT I of Monaco. The vast finds collected from these cruises are displayed to the general public in the magnificent »Musée Océanographique» of Monaco, (inaugurated in 1910). Beginning his scientific work in 1885 the Prince disposed in succession over 4 ocean-going vessels, built of increasing tonnage and perfection in their equipment. The last and largest of these, the »Hirondelle II» came into commission shortly before the outbreak of the I:st world war brought all scientific activities on the high seas to a standstill.

Always in favour of international cooperation in the sciences of the sea the Prince invited distinguished oceanographers of different nationalities to accompany him on his cruises and to work up their results in the laboratories of his museum.

Both from Denmark and from Norway deep-sea expeditions were launched, mainly to polar regions on board the »Vöringen» 1876—78, the »Fram» 1891—93 and the »Ingolf» 1895—96. For several decades Swedish efforts were mostly concentrated within the Scandinavian waters. A pioneer achievement was the excellently planned and equipped Swedish expedition of 1877, led by F. L. EKMAN. Its field of work extended from the northermost Gulf of Bothnia through the whole of the Baltic Seas, the Belts and the Sound into the Kattegat and the Skagerak. This great effort may be said to have marked the birth of Swedish Oceanography.[1])

[1]) It is of interest to note here that one of the incitaments to the »Challenger» Expedition was a notice published in »Nature» of 1871 p 107 that the governments of Germany, Sweden and the USA were preparing to dispatch ships to various parts of the ocean, expressly fitted out for deep-sea expeditions.

[1]) For a review of early work in Deep-Sea Oceanography up to 1911, see »Depths of the Ocean» by J. MURRAY and J. HJORT p. p 1—21.

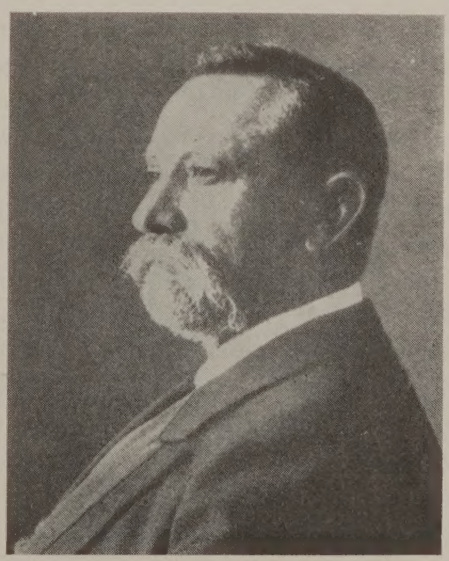


Fig. 2. Prince ALBERT I of Monaco.

Fig. 3. The »Hirondelle II».

At the beginning of this century, in 1901—03, there was an outburst of activity directed to Antarctic waters, where the British Antarctic Expedition on board the »Discovery» under SCOTT, the German South Polar Expedition on board the »Gauss» under DRYGALSKI and the Swedish South Polar Expedition on board the »Antarctic» under O. NORDENSKJÖLD, were simultaneously engaged in the exploration of different portions of the Antarctic regions and the surrounding water masses. In addition the Scottish National Antarctic Expedition in 1902—04 on board the »Scotia» under BRUCE was also working in the far south.

In this necessarily very summary account it would be unfair not to mention important contributions to deep-sea research made from the U. S. by ALEXANDER AGASSIZ on board the »Blake» (1877—80), and the »Albatross» (1899—1900) from Germany by the »Plankton Expedition» 1889 on board the »National» under HENSEN, the German Deep-Sea Expedition on board the »Valdivia» under CARL CHUN (1898—99), from Holland the »Siboga» Expedition under MAX WEBER to the Dutch East Indies, from France on board the »Travailleur» (1880—82) and the »Talisman» (1883), and from Italy on board »Washington» (1881—1885) and the »Vettor Pisani» (1882—1885).

Already before the beginning of this century an important start in organized international research was made on Swedish initiative. In 1890 O. PETTERSSON and G. EKMAN, in collaboration with Scandinavian and British colleagues started systematic investigations in the North Sea and adjacent waters. Later through their efforts an international conference was called together in Stockholm in 1899 from which, three years later the International Council for the Exploration of the Sea emanated with its head offices in Copenhagen. The number of participating nations along the coasts of NW Europe gradually increased from the original 8 to 14.

One of the first objectives of this organization was to work out dependable methods and instruments for oceanographic observations and computations which in fact transformed oceanography into an exact science. Moreover, joint quarterly cruises were sent out to predetermined »international stations», where the hydrographic elements were observed and plankton collected. The results were published in the »Hydrographic Bulletin». At the same time more exact methods for biological work, plankton studies and fishery investigations were evolved. At annual meetings of the Council, held either in Copenhagen or in other capitals of the participating countries, the program of work and its results was discussed. From this great organized methodological work, primarily developed for the shallower seas, deep-sea research has largely profited.

Some attempts to extend the work of the International Council over the much vaster field of the open Atlantic Ocean were also made. An opportunity for such an extension was offered in 1913, when the goverment of the U. S. invited different European countries to send over warships to the opening of the Panama Canal, scheduled for the summer of 1915. Together with his colleagues O. PETTERSSON drew up a plan for combining these transatlantic cruises with oceanographic observations by scientists on board the naval vessels. These were to be equipped with the

necessary instruments for studying the water-layers from the surface downwards to a depth of 1 000 metres. Salinity- and temperature-measurements were to be included in the program and also the sampling of plankton, fish eggs and larvae. From seven of the participating countries favourable answers to this proposal were received and the Swedish Riksdag voted the means required for carrying out Sweden's part in the work. The plan received enthusiastic support from the Prince of Monaco. He undertook to carry out, conjointly with the international cruise observations in the eastern part of the N Atlantic Ocean from his new research yacht the »Hirondelle II». One of the main objectives of the planned synoptic investigations was to obtain a clear picture of the heat reserves stored in the water masses of the Atlantic surface layer especially in the Gulf Stream Drift, from which the influence on the climate of NW Europe had for many years been studied by O. Pettersson. In this way an opening might be attained for bringing the influence of the sea on meteorological and climatic conditions within the field of work of the International Council.

Unfortunately the outbreak of the I:st World War prevented the realization of this great scheme. In fact the political and financial crises which followed on the war made it impossible to resume this ambitious program.

After the death of Prince Albert in the summer of 1922 his yacht, the »Hirondelle II», was offered for sale for the benefit of the Monaco Foundations. Together with his friend Commander C. Drechsel, then General Secretary to the International Council, O. Pettersson (1923) drew up a plan for acquiring the yacht as the property of the International Council and to equip it for a great deep-sea expedition lasting for 4 years, of which the first year was to be devoted to the Atlantic Ocean the two following years for work in the Pacific Ocean and the fourth year to the Indian Ocean. The total costs including the price of the »Hirondelle,» 2 000 000 francs, were somewhat optimistically estimated at 10 to 14 million francs (at the rate of exchange then existing equivalent to between 120 000 and 140 000 £). The plan was put before the International Council at its meeting in Paris in October of 1923 and was, in principle, agreed to. However, the difficulty of obtaining the financial backing necessary for its execution was found insurmountable. Instead the »Hirondelle» was acquired by a film company and was permanently lost to science.

Modern Deep-Sea Expeditions

The first deep-sea expedition with modern equipment was that carried out in 1910 on board the Norwegian research ship the »Michael Sars» by Sir John Murray and Dr. J. Hjort. Its field of work was limited to the N. Atlantic Ocean and its program was mainly biological. However, a small number of deep-sea deposits were also collected, none of the cores exceeding 40 cms in length. Physical oceanographic work was mainly limited to salinity- and temperature-observations. In addition, a few measurements of submarine daylight and of the subsurface currents, especially in the Straits of Gibraltar, were made. From the »Michael Sars» a large trawl was for the first

Fig. 4. Sir. John Murray.

Fig. 5. The »Meteor.»

time used in great depths and a fair number of deep-sea fishes, both pelagic and bottom-living were caught, several of them new to science. MURRAY & HJORT, Depths of the Ocean.

The outbreak of the I:st world war paralyzed for over a decade all attempts at carrying out deep-sea research. The renaissance of the study of the open oceans was heralded by the great German Atlantic Expedition with the »Meteor» 1925—27. The originator of the cruise the Austrian oceanographer ALFRED MERZ, who partook in it until his untimely death in August 1925, had planned a vast cruise into the Pacific Ocean. For lack of a ship with a sufficiently great radius of action this ambitious plan had to be abandoned. The »Meteor» cruise was instead limited to the Southern and the Equatorial Atlantic, across which 13 transoceanic sections were made. The equipment was of the most perfect kind obtainable at that time and included an echosounder which enabled the expedition to make no less than 67 000 depth measurements, the majority in great depths.

The main objective of the »Meteor» expedition was physical and chemical oceanography, involving a very thorough study of the different water strata filling the Atlantic ocean basin, their origin and their movements. Current-measurements down to unprecedented depths were carried out from the ship at anchor over depths sometimes exceeding 4 000 metres. In addition extensive plankton studies were also made, combined with measurements of the nutrient salts present in different regions and depths of the area investigated.

The results from the »Meteor» Expedition, carefully analyzed by the foremost specialist in different sciences, were published in a series of quarto volumes. They have been of very great importance to modern oceanography and have laid a foundation for our knowledge of what might be called the anatomy and the physiology of the Atlantic water masses, as well as affording a highly advanced picture of its bottom configuration. In one respect, however, the equipment of the expedition was not very adequate. Its coring tubes for sampling the deep-sea deposits were comparatively short, so that the cores obtained never exceeded 1 metre in length.

A number of shorter cruises with other ships like the »Altair» and the »Emden» a. o. working within the middle latitudes of the N. Atlantic Ocean supplemented the »Meteor» Expedition. Their echo soundings added greatly to our knowledge of the Açores Plateau and of the neighbouring parts of the Midatlantic Ridge.

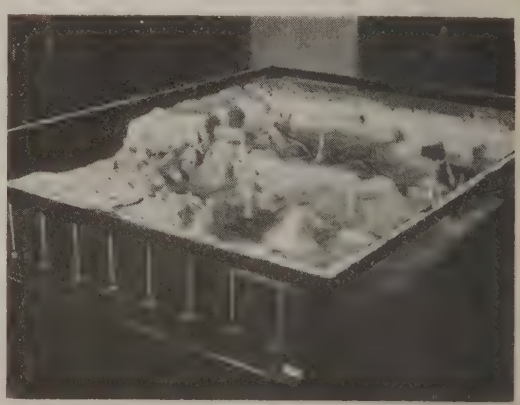


Fig. 6. Relief map of Atlantic Ocean.

The Danish circumnavigating expedition with the »Dana» under JOHANNES SCHMIDT (1928—1930) was chiefly devoted to the studies of the uppermost 1 000 metres of the ocean and their biology, especially investigations of the eels and their propagation in the different oceans. However, thanks to its echo-sounder the Dana-expedition discovered the »Carlsberg Ridge» in the NW Indian Ocean.

An important expedition limited to the SE Indian Ocean and especially to the Indonesian Seas, extended as far north as to the Mindanao Deep, was sent out from Holland with the »Willibrord Snellius» and led by P. M. VAN RIEL (1929—30). Also this cruise had bathymetrical and physico-chemical oceanography as its main objective. A large number of hydrographic sections through the different basins of the Sunda Archipelago with studies of the bottom deposits (maximum core-length 2.10 metres) were made. In certain stations also current-measurements were made from the ship when at anchor over great depths.

Into the NW parts of the Indian Ocean, which had not been visited by the »Challenger», deep-sea research was carried out by an Anglo-Indian Expedition, the John Murray Expedition[1]) on board the »Mabahiss» in 1933—34. Its most important results were bathymetrical and studies of the different water strata and, to a limited extent, also of the bottom deposits.

The »Discovery» Committee of the Colonial Office in London during a number of years sent out of expeditions with the »Discovery II» the »Scoresby» and other ships to Antarctic waters. The study of the whales, their food, their propagation and their migration was the chief objective. In addition valuable data regarding the oceanography of the Antarctic seas have been published from these cruises in the »Discovery Reports».

From Woods Hole Oceanographic Institution a number of cruises were sent out with the »Atlantis» and other ships, their main field of work being the NW parts of the Atlantic Ocean. In the Pacific Ocean cruises with the non-magnetic ship the »Carnegie» (1928—29) were directed from Scripps Institution. The results gave valuable contributions to our very limited knowledge of that ocean. One American expedition which, from a technical point of view, is of special interest was that on board the »Carnegie» in 1936 when the new explosive deep-sea corer invented by C. S. PIGGOT was used (PIGGOT 1936). Cores ranging from less than 1 metre to nearly 3 metres in length were raised from the bottom of the NW Atlantic between New Foundland and Ireland. The geological study of the cores made by BRAMLETTE gave important stratigraphical results. (BRAMLETTE and BRADLEY 1940).

The outbreak of the II:d world war put a stop to all activities on the open oceans except for certain valuable observations, mostly bathymetrical, carried out in the Pacific and the Atlantic Oceans by American warships. Their observations are, however, unfortunately still to a great extent »classified», i. e. not available to scientific work and discussions.

Swedish Oceanographic Research in the XX:th Century

In 1893 G. EKMAN and O. PETTERSSON prevailed on the Swedish government to set up a marine research commission, »Svenska Hydrografiska Kommissionen». Eight years later, by the inclusion of representatives for Swedish fishery investigations and plankton work, it was extended into »Svenska Hydrografisk-Biologiska Kommissionen», which was charged with the carrying out of Sweden's share of the research program agreed on by the International Council. Into this commission, beside EKMAN and PETTERSSON, entered scientists active in Swedish universities and seats of

[1]) By the will of Sir JOHN MURRAY capital had been set aside for financing a deep-sea expedition to the NW Indian Ocean.

Fig. 7. Otto Pettersson.

learning like E. A. Wijkander, C. W. S. Aurivilius, P. T. Cleve, F. Trybom a. o. The members of the commission received no salary but had at their disposal a moderate government grant for expenses and publications as well as salaries for a few trained assistants. The whole set-up was of a distinctly anglosaxon type with scientific interest as the motive power.

Together with G. Ekman, O. Pettersson had a research station built on the island Bornö in our greatest and deepest fjord, the Gullmar Fjord. For many years Bornö Station remained the centre of Swedish oceanographic research. At first no research ship was available, but through generous cooperation on the part of the Swedish Navy gun-boats stationed on the west coast of Sweden were set at the disposal of the scientists for short expeditions.

On the proposal of the commission the Swedish Riksdag in 1903 voted the sum required for the building of a research ship, the »Skagerak», a steamship of 450 tons with a steam

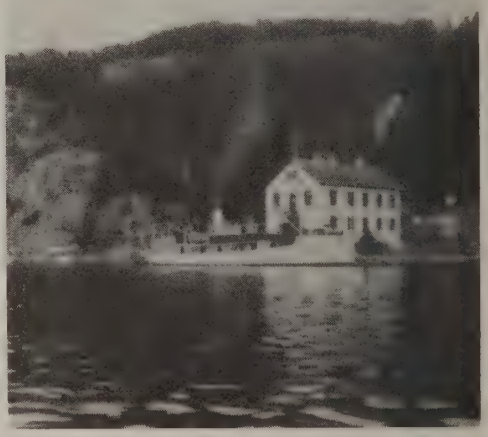


Fig. 9. The Skagerak at Bornö Station.

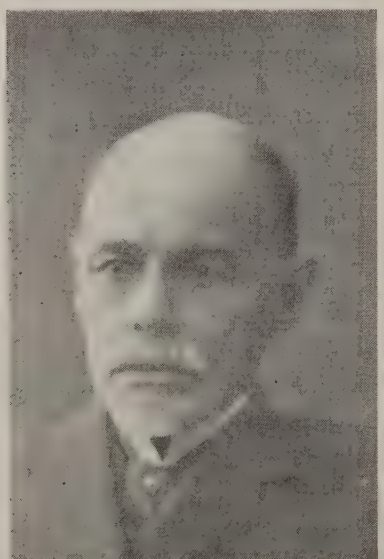


Fig. 8. Dr. Gustaf Ekman.

engine giving it a speed of 9 knots. With this small but excellent ship a great number of expeditions were carried out, mostly within the Scandinavian waters, occasionally extended into the North Sea. On board the »Skagerak» O. Pettersson in 1907 discovered in the Great Belt remarkable boundary movements of tidal period (o. Pettersson 1907) a discovery which was at first hotly contested by other oceanographers.[1])

In the fall of 1908 O. Pettersson followed

[1]) In this well known textbook »The Oceans» H. U. Sverdrup ascribes this discovery to his countrymen F. Nansen and B. Helland-Hansen who found rythmical boundary movements to occur in the opean sea, observations which they published in 1909.

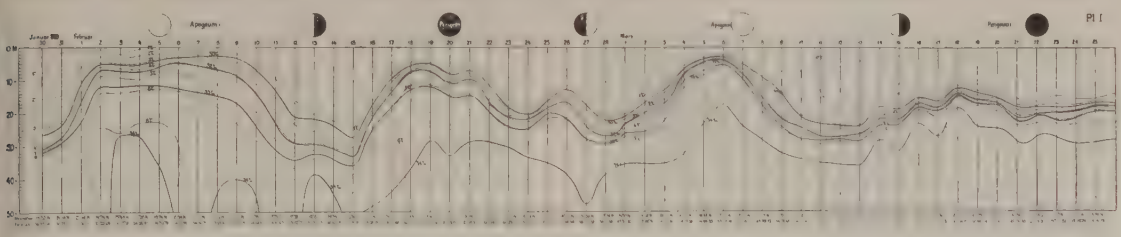


Fig. 10. Internal movements in the Gullmar Fjord.

up this discovery by organizing daily oceanographic soundings in different depths from the surface down to the bottom (at 34 metres) from an observation pier near Bornö Station. He found that the stratified water in the Gullmar Fjord is in a continuous state of internal motion, involving large upheavals and subsidences of the boundary, with vertical displacements of up to 20 or even 30 metres, accompanied by corresponding horizontal displacements, into and out of the fjord basin, of millions of cubic metres taking place in the course of a few days. These internal movements were found to exert a distinct influence both on the plankton and on the fishes migrating into or out of the fjord, as well as, in winter time, on the formation and the breaking up of the ice.

During this classical aera of Swedish oceanographic research Bornö Station became a focus of interest also to international marine research and was accordingly visited by a number of students and of leaders in oceanography from different countries. Beside the studies in physical and chemical oceanography biological research of practical importance was made near Bornö, as the discovery of large quantities of the Arctic prawn, *Pandalus borealis* in the depths of the fjord.

In 1928 one of Sweden's greatest benefactors to science, the late K. A. Wallenberg gave a sum sufficient for establishing a biological research station for the Kommission, »Havsfiskelaboratoriet» in Lysekil at the entrance to the Gullmar Fjord. Four years later the same donor made it possible to acquire Bornö Station as government property, at the same time providing it with a new modernized equiment, an electric plant, increased space for its library etc. However, also with these improved working facilities experience gained at Bornö made it appear highly desirable to establish a more powerful and better equipped oceanographic institute in Göteborg. Again Wallenberg agreed to donate the large sums required for this purpose. The recipient of the donation was the Royal Society of Göteborg (Göteborgs Kungl. Vetenskaps och Vitterhetssamhälle, founded in 1778.) The new institute: Oceanografiska Institutet, was inaugurated in January 1939.

Already 25 years earlier, in 1914, G. Ekman had bequeathed a sum to Göteborgs Högskola for the foundation of a lecturership in oceanography with a small adjoined laboratory. In 1930 another wealthy Göteborger, Mr. Knut Mark together with his wife Ingeborg Mark bequeathed a sum to the Högskola, sufficient for founding there a chair in oceanography. Nine years later the holder of the chair (the present author) was nominated director of Oceanografiska Institutet.

Thanks to the excellent workshop and other resources of the Institute it became possible for us working there to utilize the forced inactivity in the open sea, due to the II:d world war, for planning and preparing a Swedish deep-sea expedition. The origin of this enterprise will be summarily set out in the following.

The Origin of the Swedish Deep-Sea Expedition

In 1908 Professor John Joly of Trinity College in Dublin, to whom Sir John Murray

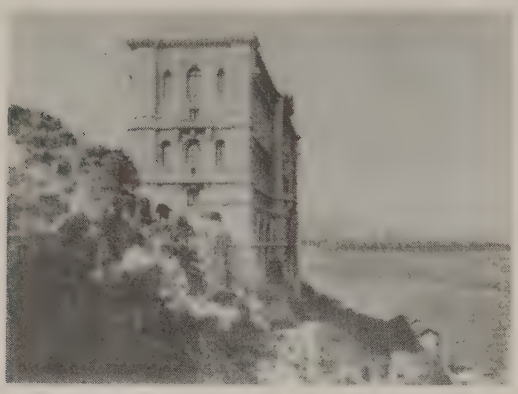


Fig. 11. Musée Océanographique.

had sent some of his samples from deep-sea deposits for radium analysis, published sensational results (JOLY, 1908). In some of the samples JOLY found a radium content as high as 40 to 50 units of the 12:th decimal place in gram per gram,[1]) i. e. values ten to twenty times higher than those usually found in continental rocks.

At first JOLY inclined to the view, that this high radium content may be due to a precipitation of radium itself, from the supernatant column of seawater as highly insoluble sulphate of radium. Later he went over to assume that the abyssal radium is produced *in situ* through the continuous disintegration of a correspondingly high content of uranium in the deposit. For this hypothesis Joly believed to find support in results from a colorimetric analysis of the uranium in red clay, carried out by Prof. WERNER in Zürich. My own first contact with the problems of deep-sea radium. I had in June 1912 during a short cruise in the North Sea on board the Norwegian research ship the »Michael Sars», as the guest of Sir JOHN MURRAY and Dr. JOHAN HJORT. Two years earlier they had conjointly made a deep-sea expedition with the same ship into the N Atlantic Ocean and had obtained very important results.

[1]) This unit in geophysical radioactivity, written $10-^{12}$ gr Ra/gr corresponds to one thousandth of a milligram of radium per metric ton of the material.

Having some years earlier worked with radium under K. ÅNGSTRÖM in Uppsala, and being in 1912 engaged on research work under Sir WILLIAM RAMSAY at University College in London, I was greatly tempted by an invitation from Sir JOHN MURRAY to come over to his »Challenger Office» near Edinburgh in order to work up its unique collection of deep-sea deposits for radium. At that time MURRAY believed that deep-sea radium is mainly of volcanic origin, so that plotting the distribution of radium found within an area of the deep-sea floor, it might be possible, by drawing on a chart lines of equal radium content, to locate the unknown submarine craters from which the radium was supposed to have come.

For pressure of other work I had, to my regret, to decline this invitation, although my interest in the radioactive problems continued very great. When finally, 8 years later, I had an opportunity to take up this work, thanks to a sabbarian leave from my teaching duties in Göteborg, Sir JOHN MURRAY had passed away. From another one of my father's friends, Prince ALBERT of Monaco, I received an invitation to work in his magnificent Musée Océanographique of Monaco, where another large collection of deep-sea deposits, second only to that in the Challenger collection, was stored. Together with my wife, a trained chemist, who helped me in my studies, we started our work in Monaco in the fall of 1921.

Although our work was facilitated in every way by the director of the Museum, M. J. RICHARD and his staff, I soon found that the resources available in Monaco were not adequate for making exact measurements. Having there obtained samples from different cores and converted them into soluble form, I accepted an invitation from Prof. ST. MEYER, director of the Institut für Radiumforschung in Vienna and moved over to that city in the beginning of March 1922. There we met with the generous help both from St. Meyer and his staff and also from his colleague Hofrat H. MACHE of the

Technische. Hochschule in Vienna, in whose institute several of the more delicate measurements were carried out.

The deep-sea deposits from the Monaco collections, later supplemented with samples from the »Challenger» collection, which were kindly set at my disposal by the authorities of the British Museum of Natural History in London, gave results which confirmed the high radium values found by JOLY (PETTERSSON, 1930). However, none of the three explanations for the source of abyssal radium so far suggested was found satisfactory, and for the time being the origin of deep-sea radium remained a mystery. The solving of this mystery required a decade of sustained work, carried out partly in Vienna partly in Göteborg, in close cooperation with experts from the Institut für Radiumforschung. This work involved a detailed study, not only of radium but also of its ancestral element uranium present in seawater. The final solution, published in 1937, (H. PETTERSSON 1937) was that the high radium content in red clay and in similar deposits from great depths is due to the precipitation of ionium (the immediate parent element of radium) from seawater on to bottom where, in the course of several thousand years, its descendant radium is bred. Details from these investigations and their results will be given further on in these Reports. Suffice it to say at this stage, that to myself the radium work in Monaco and in Vienna had its most important result in giving rise to a strong craving for further samples from deep-sea deposits, especially such obtained in the shape of much longer cores, reaching further back in time than those until then avialable. The dream of a Swedish deep-sea expedition with a sampling of the carpet over the deep-ocean floor as its main objective gradually began to take shape. That it would take nearly a quarter of a century before that dream would materialize, I could not at that time foresee. In case the plan had been realized which was put forward in 1923 by

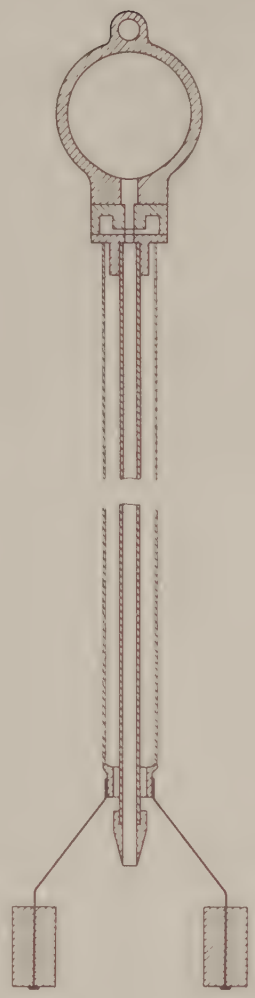


Fig. 12. The vacuum corer.

my father O. PETTERSSON and Commander DRECHSEL before the International Council in Paris (PETTERSSON and DRECHSEL, 1923), to acquire the splendid yacht of the late Prince ALBERT, the »Hirondelle II» for a circumnavigating deep-sea cruise lasting for four years, the opportunities for sampling the ocean floor for radium analyses would probably not have been neglected. However, the proper technique for achieving such a sampling in a satisfactory manner had not at that time been evolved.

In 1930 I was fortunate to acquire as my collaborator, Dr. BÖRJE KULLENBERG endowed both with technical skill and constructive power. Already at an early stage I told him

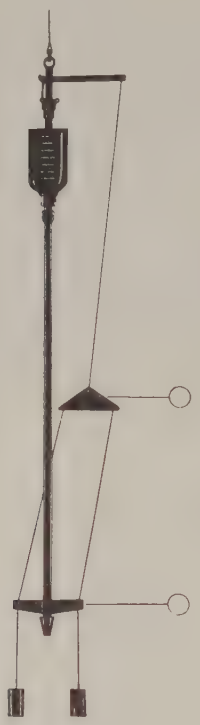


Fig. 13. Sketch of piston corer.

of my plans for obtaining sediment cores of unprecedented length by utilizing the hydrostatic pressure in great depths. Together we developed a construction called the »vacuum corer» (PETTERSSON and KULLENBERG 1941). In this instrument a thickwalled container, attached to the upper end of a long coring tube made from steel, is evacuated, just before the instrument is lowered to the bottom. A plunger, kept in position by strong arrests, prevents the seawater from entering prematurely into the vaccum container. At contact with the seabottom this plunger becomes released and at the same time as the heavy coring tube sinks down into the deposit a column of the latter is, by the high pressure of the surrounding water, forced to rise inside the tube, filling it with practically undisturbed sediment. By means of this instrument a sediment core was in 1942 raised from the bottom of the Gullmar Fjord exceeding 14 metres in length, i. e. nearly five times longer than the previous record length obtained with the PIGOTT corer.

However, KULLENBERG was not satisfied with this solution of the problem and foresaw, that difficulties would arise, when the vacuum corer was to be used in great ocean depths. He therefore developed a different instrument, the so-called »piston-corer», in which there is no evacuated container but instead inside the coring tube a piston, initially kept fixed at its lower end until the bottom is approached. (KULLENBERG, 1947). Then, by a release mechanism the piston, remaining attached by an internal wire-rope to the main wire at its upper end, is suddenly stopped, so that the piston remains immovable, the heavy corer with its attached weights is detached from the main wire rope so that it descends into the deposit to its full length. The piston rising passively inside the sinking tube is, owing to the high water pressure, followed by a column of sediment, secured from sliding back by means of a catch in the bit.

This instrument which proved both more efficient and more easy to handle in great depths than the vacuum corer, was to become our main tool in attacking the problems of the deep ocean floor.

Fig. 14. Prof. W. WEIBULL.

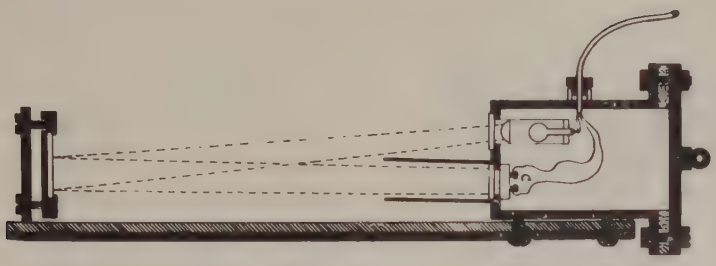


Fig. 15. Transparency meter.

We had also other strings to our bow. Our foremost authority on explosives, Prof. W. WEIBULL of the Bofors Armament Works, had asked me for permission to use the facilities of Bornö Station for certain experiments there with exploding subsurface charges, a permission which was readily granted. At the same time I asked him to help us with developing a seismic method for measuring the thickness of deep-sea sediments, a proposition to which WEIBULL agreed. Thanks to his excellent connections with the Bofors Works and with the Swedish Navy, WEIBULL was able to work out practical methods for setting up submarine explosions and for recording the echoes thrown back against boundary layers in the sediment. In this way he could obtain values for the vertical distance between the reflecting layer and the sediment surface, a quantity which at that time was perfectly unknown in great ocean depths.

KOCZY and JERLOV, using a technique devised by KOCZY and KULLENBERG, were able to collect uncontaminated water samples, and measure the temperature, at accurately determined levels near the bottom at great depths.

The great importance for marine biology of submarine daylight and, in connection with this, the transparency of seawater, had made us take up this problem from Bornö Station and the »Skagerak» (PETTERSSON, H. 1934 a, 1934 b, 1936 a, 1936 b) PETTERSSON, H. and S. LANDBERG, 1934, JOHNSON, N. G. and G. LILJEQUIST 1938, JOHNSON 1944, 1946.) New and efficient instruments for carrying out such measurements in moderate depths were constructed and found to be very useful for studying the optics of the sea, especially in conjunction with the photosynthesis of its phytoplankton. In addition these optical methods have proved useful for differentiating between water layers in the highly stratified coastal waters. To pursue these studies also in great ocean depths appeared feasible but required a different kind of technique, owing to the impossibility of handling electric cables of greater length than a few hundred metres.

Dr. N. G. JERLOV (JOHNSON), who has specialized on the optical properties of seawater and on the propagation, the absorption, the scattering and the reflexion of submarine daylight, in particular the ultra-violet components, decided on the highsensitive Tyndall method for studying water samples raised from great depths. Focussing a strong beam of parallel light into a small quartz flask filled with the sample he was able to measure the intensity of the light scattered through an angle of 45° against the minute and very rare particles present in the water. In this manner the »turbidity» of the ocean water collected in different depths from the surface down to the immediate proximity of the bottom could be investigated. From the results important conclusions regarding the origin of the particles were inferred.

To one of the specially interesting tasks before a deep sea expedition I have already referred above, viz. the study and measurement of the radioactive elements, especially uranium and radium present in the water and in the

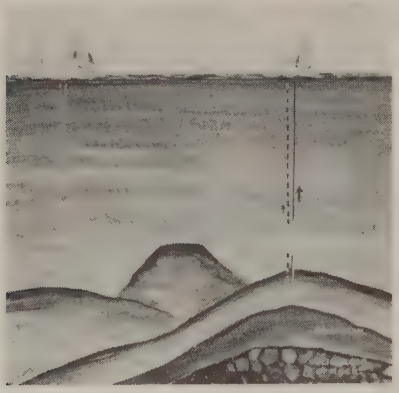


Fig. 16. Principle of echo-sounding.

deposits. Methods for this purpose had been worked out during many years and could easily be adapted for deep-sea work. Owing to the scarcity of radium present in ocean waters, of the order of units of 10^{-17} gr/gr, fairly large quantitites of seawater had to be collected and the radium extracted through a co-precipitation together with sulphate of baryum. In order to obtain the requisite volume of seawater also out of great depths special water-samplers of great capacity, from 8 to 25 litres, had to be constructed. The quantity of water required for analyses on uranium being much less, the sample for this purpose could be taken from the same large sample before the chloride of barium necessary for precipitating the radium had been added. As it was impractical to carry out radioactive measurements on board a ship, the precipitates of baryum-radium sulphate and the litre flasks with the uranium samples had to be stored on board and analysed in the laboratory after the return of the expedition.

A problem in which I was personally most interested was that of measuring the temperature gradient in the deep-sea deposits, at that time an altogether unknown quantity. The »geothermometer» constructed for this purpose will be described later on in this Report. Unfortunately the clockwork enclosed in it proved to be of a very inferior make and most often struck work at the low temperature characteristic of great ocean depths. Only a few dependable measurements could, therefore, be made. They proved, however, of great interest and have received ample confirmation through similar measurements made later from American expeditions.

One requirement essential for the successful carrying out of our plans to work in great ocean depths was a trustworthy and accurate sounding equipment. To measure the water depth by means of mechanical soundings is a most laborious operation, requiring hours for the determination of a great ocean depth. Fortunately, already before the I:st world war and especially between the wars, accoustic sounding methods had been evolved, in which ultrasonic waves generated on board are projected towards the bottom, from which the returning echoes are recorded. This obviously represents a radical improvement in the sounding gear. Thanks to the high velocity of sound in water, about 1 500 metres per second, an echo—sounding of the greatest ocean depths, $\approx$ 10 000 m, requires less than a quarter of one minute! Consequently the frequency of accoustic depth-measurements can be increased many hundredfold over what is possible with the most modern mechanical sounding machines.

A technical improvement of the greatest importance for our purposes was that of the recording echo-sounder or »echograph», which draws a continuous record of the configuration of the bottom over which the ship is passing. For the success of the operations with deep-sea corers or with trawls, a dependable echograph of great range and high accuracy is a *conditio sine qua non*. Moreover, records from such an instrument afford unprecedented opportunities for studying the previously unknown morphology of the deep ocean bed and even its micro-structure.

Thanks to many years of experience from echosounders and echographs of different constructions on board the »Skagerak», we had been

convinced of the necessity of acquiring the very best equipment obtainable of this kind. On the recommendation from the British Admiralty I approached the wellknown London firm Marine Instruments Co (formerly HUGHES and SON), with a request for an echograph which could draw detailed bottom curves down to depths of at least 7 000 metres.

This demand met with a very generous response. The experts of the firm set themselves the task of constructing an instrument equal to the very high demands I had set before them. The new instrument, constructed specially for us, was first installed on board the »Skagerak» and very thoroughly tested during the preparatory cruise to the Mediterranean. The results called for diverse improvements, which were carried out in the year between the two expeditions. The instrument finally developed was mounted on our expedition ship the »Albatross» where it did excellent service. A detailed description of the equipment will be given in volume IV of these reports (KOCZY 1956).

Table of Expeditions devoted mainly to deep sea research

British Antarctic Expedition under Sir James Clark Ross.	1839—43
Swedish Arctic Expeditions under A. E. Nordenskiöld	1861—83
U S Coast Survey Expeditions under Pourtalès and L Agassiz	1867—70
British Expeditions N Atlantic & Mediterranean W Thomson & W Carpenter	1868—71
British Expedition with H M S Challenger under Thomson a o	1872—76
U S »Tuscarora» under Belknap in the Pacific	1872—76
Norwegian N Atlantic Expedition on »Vöringen»	1876—76
U S Coast Survey expedition with the »Blake» under A Agassiz	1877—80
U S Fish Commision »Albatross» under A Agassiz	1899—1900
British Expeditions with »Knight Errant» and »Triton» to Faroe Channel	1880—82
French Expeditions with »Travailleur & »Talisman» E. Atlantic	1880—1883
U S »Enterprise» circumnavigating expedition	1883—86
Prince Albert of Monaco cruises into Mediterranean and N Atlantic	1885—1910
Russian Expeditions with Vitiaz under Makaroff circumnavig...	1886—89
German Plankton Expedition on the »National» under V Hensen	1889
Austrian Expeditions with the »Pola» in the Mediterr & Red Sea	1890—98
Norwegian N Polar Expedition with the »Fram» under Nansen	1893—96
Dansk djuphavsexpedition with »Ingolf» into N Atlantic	1895—96
Belgian Antarctic Expedition with the »Belgica»	1897—99
German Deep Sea Expedition on the Valdivia under Carl Chun	1898—99
U S »Albatross» under A Agassiz in the tropical Pacific	1899—1900
Dutch East India Expedition under M Weber with the »Siboga»	1899—1900
British National Antarctic Expedition under Scott	1901—03
German S Polar Expedition on the »Gauss» under V Drygalski	1901—03
Swedish S Polar Expedition on board the »Antarctic» under O Nordenskjöld	1901—03
French Antarctic Expeditions under Charcot on Board the »Francais»	1903—05
French Antarctic Expeditions under Charcot on Board the «Pourquoi Pas?»	1908—10
British Antarctic Expedition on board the »Nimrod», under Shackleton	1907—09

Norwegian Expedition with the »Michael Sars» under Murray & Hjort	1910
German Atlantic Expedition with the »Meteor» under A. Merz	1925—26
The Carlsberg Foundation's Oceanographical Expedition round the World with the »Dana» Expedition under J. Schmidt	1928—10
The Snellius-Expedition under P. M. van Riel	1929—30
The John Murray Expedition under R. B. Seymour Sewell	1933—34

The Test Cruise with the »Skagerak»

The test to which our new technique had been submitted in Swedish fjords and off the Swedish coasts had given encouraging results. It was however, considered advisable to carry out further tests in still greater depths, before venturing to use the new instruments and methods in the open oceans. Permission to dispose over the Swedish research ship the »Skagerak» for a preparatory cruise was granted by Svenska Hydrografisk-Biologiska Kommissionen and was also confirmed through a resolution by the Swedish Government in August 1945.

The »Skagerak», the second of this name, had been built in 1935 and had been extensively used for cruises within Scandinavian waters. It has a displacement of 550 tons d. w., a length of 47 metres and a draught of 4.2 metres. Its twin engines of the »JOHANSSON» type give it a speed of 10 knots, which can be raised to 12.5 knots. It is well provided with laboratories and with accomodation for a staff of 6 to 10, and was ably commanded by Captain GUSTAF HOLMSTRÖM. Its main drawback for our purposes was its trawling winch, wich had been transferred from the old »Skagerak». It was none too powerful and in addition badly worn for use. It almost broke down under the heavy strain from corers weighing up to one ton. This danger limited the length of the cores we could safely raise to less than 16 metres.

As the most suitable region of the sea for our experimental work we decided on the western Mediterranean. There, within easy reach of good harbours, depths exceeding 2 000 metres are to be found. Moreover in the Mediterranean,

Fig. 17. The »Skagerak» off the Swedish coast.

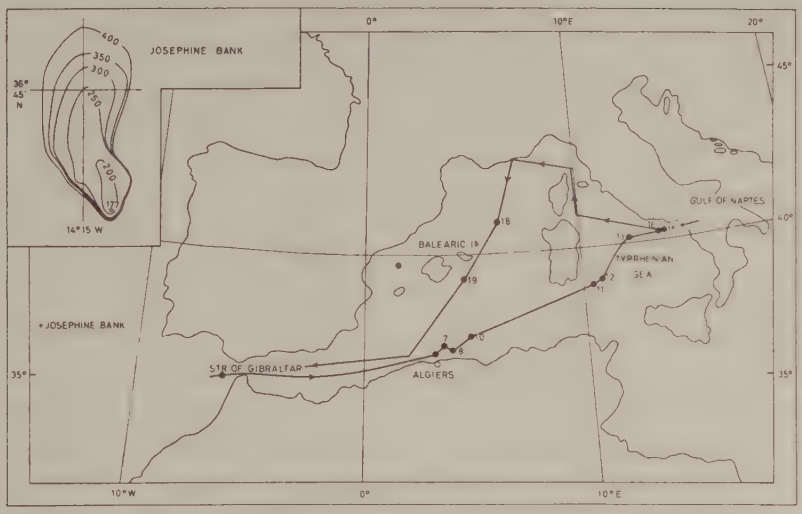


Fig. 18. »Skagerak» cruise in the Mediterranean.

during the spring months, April and May, one is generally favoured by light winds, moderate swell and high visibility. Finally, owing to the many volcanoes, some of them still active, found near the coasts or on the islands of the Mediterranean the chances of finding stratified deposits with distinct boundaries between the different layers are considerable. From the undisturbed shape of such layers the proper functioning of the coring tube could be inferred.

Beside the present author and Dr KULLENBERG, who headed the coring operations, assisted by our trawling-master Mr. A. NILSSON and by our excellent mechanic Mr A. JONASSON, the science staff consisted of Prof. WEIBULL and his assistant, Mr LUNDGREN of Bofors, and of fil. kand. G. ARRHENIUS. During the first part of the cruise, from Göteborg to Lisbon, we had on board two representatives of the Marine Instruments Co of London, who were occupied with the supervision of the recording echo-sounding apparatus specially constructed for this cruise.

The »Skagerak» left Göteborg on April 4th 1946, touched at Lisbon on the 12:th and from there ran into the Mediterranean reaching the port of Algiers on April 19:th. We had chosen this port as the first base of our operations, partly owing to its excellent harbour, partly owing to its proximity to depths exceeding 2 000 metres, situated only 20 to 50 nautical miles to the north of the African coast. In a few cores taken there in depths between 2 300 and 2 700 metres there were coarse-grained layers up to more than one hundred in a single core. A cursory examination made on board proved fragments of pumice and other particles of volcanic origin to be present. Later examinations carried out in the laboratory by Dr KULLENBERG proved, that in certain cases these coarse-grained layers are largely, or even mainly, made up from terrigenous material, mostly quartz grains i. e. sand. However, the transportation of such comparatively thick layers of desert sand far out into the sea must have required gales of hurricane strength. In the lower parts of some of the N African cores there were layers of vegetable fibres, filtered together, of mollusc shells and also other indications of a subsidence of the coast in a comparatively recent past.

On May 7:th the »Skagerak» left Algiers, where we had been most hospitably treated both by our colleagues at the University of Algiers and by the authorities, especially by the Gouverneur-géneral M YVES CHATAIGNEAU,

who in his youth had studied oceanography under Prof. THOULET. Also the Swedish Consul-general, R. KOHLER, was indefatigable in caring for our comfort and our entertainment.

On our way to the Tyrrhenian Sea further cores were sampled, one of them containing a coarse-grained layer 75 cms thick! In the Tyrrhenian Sea a maximum depth of 3 620 metres was reached and a core 10½ metres long successfully raised from it (Station 13). Afterwards we approached the Gulf of Naples but found the bottom in its vicinity too steep for core-sampling and also devoid of sediment. At the nearest locality, about 50 miles due west from the crater of Mt Vesuve, where a core was obtained (Station 15) the depth was nearly 2 000 metres and the length of the core obtained nearly 6 metres. At another Station (16), some 10 nautical miles from this position in a depth of 2 770 metres a core 8 metres long was raised. Here the core sampler hit on hard rock or rock fragments (limestone) some of which were retrieved from the bit of the corer.

From the Tyrrhenian Sea onwards a northwesterly course was followed which finally, on May 14:th, brought us in to the harbour of Nice. As no offical declaration had been issued at that time, that the entrance to the port of Monaco had been swept clear of mines, we had with regret to desist from taking the »Skagerak» into its harbour. However, the occasion was used to visit the magnificent Musée Océanographique of Monaco, where we were most cordially received by its director Commandant J. ROUCH.

After a stay of nearly one week at Nice, required for an overhaul of the engine, the »Skagerak» started on May 20:th on a southwesterly course. A couple of cores were raised under way, one 9 metres long from a depth of 2 680 metres half way to the Balearic Islands, the other 10 metres long from a depth of 1 850 metres to the ESE of Mallorca.

During the cruise in the Mediterranean Prof. WEIBULL had carried out several seismic soundings of the sediment thickness, which he found to increase from near the N African coast, where it was 220 metres, to a maximum of about 2 600 metres near the centre of the Tyrrhenian Sea, where the water depth was 3 620 metres. Assuming the reflecting surface to be the bedrock underlying the sediment, the vertical distance of the former below the water surface becomes 6 200 metres. WEIBULL's experiences in the Mediterranean gave rise to various improvements in his technique (WEIBULL 1947). One was the use of free depth-charges, made to explode in a certain depth by means of a hydrostatic release. The advantages of locating the explosion nearer to the bottom than with the cable-ignited charges were obvious.

It was considered desirable after the return of the expedition to submit some of the cores raised in the Mediterranean to a preliminary study by various specialists. In the Oceanografiska Institutet in Göteborg measurements of the water- and carbonate-content in the sediment were made by Dr STINA GRIPENBERG in collaboration with Mrs LILLY SNELLMAN and Dr BERTA KARLIK from the Radium Institute in Vienna. Dr. KARLIK also gave valuable help to the present author by checking his measurements of the radium content in three cores from the Tyrrhenian sea, in which a few surprisingly high values were found. The nitrogen and the phosphates in the samples were measured at Kagghamra by Drs O. and A. ARRHENIUS. A spectrographical study of various chemical elements present in the cores was made by Dr S. LANDERGREN of the Swedish Geological Survey (S. G. U.) in Stockholm. Dr O. MELLIS of Stockholms Högskola studied the minerals present in the coarse-grained layers from the same cores. Dr FRED PHLEGER of Amherst College U. S. A. studied the Foraminifera in the three cores, Mrs MAJ-BRITT FLORIN investigated the diatoms, whereas Assistent C. LARSSON of SGU investigated the pollen grains present in different layers of the cores.

The results from these studies, which were of

Fig. 19. Coarse-grained sediment in Tyrrhenian core.

importance also for the planning of the coming deep-sea expedition, were published (Pettersson 1948, Phleger 1947) from Oceanografiska Institutet.

In general the experiences gained from this preparatory cruise in the Mediterranean were encouraging. They led to various improvements in the instruments and the gear used. Also for the fitting out of the expedition ship, the experiences gained from the cruise with the »Skagerak» were of great value. Especially the superiority of Dr Kullenberg's piston corer over all other coring devices was manifest.

After passing through the Straits of Gibraltar the »Skagerak» touched at the port of Tangiers where Dr O. Nybelin, Director of the Natural History Museum of Göteborg joined the expedition. During the following two weeks he directed biological work by means of trawls and plankton nets in the depths to the west of the Straits of Gibraltar and off the SW coast of Portugal. Valuable collections were made both of invertebrate organisms and of fishes, including three fishes new to science.

Profiting from an exceptionally calm weather the »Skagerak» visited the Josephine Bank at 36° 45′ N, 14° 15′ W. By means of the echo-sounder the depths over the bank were measured. Attempts at dredging on the summit of the bank failed, the net of the dredge becoming badly torn.

On the return voyage with the »Skagerak»,

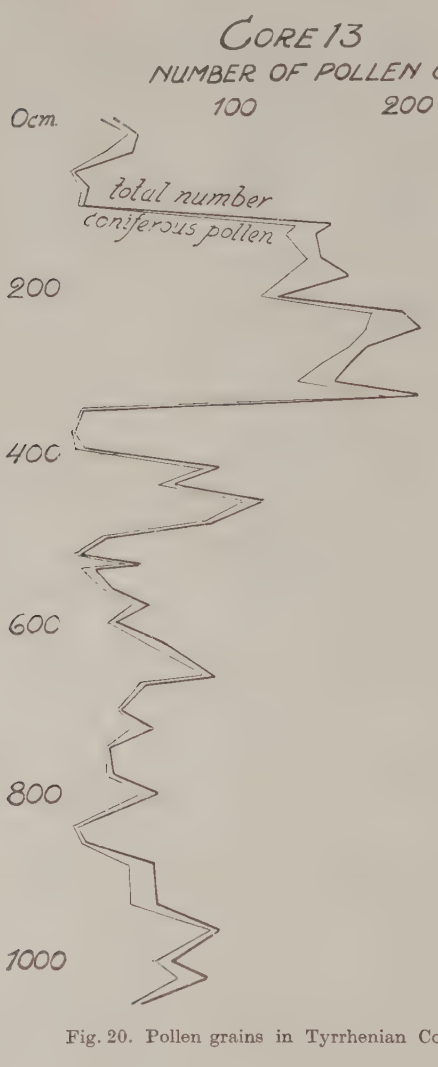


Fig. 20. Pollen grains in Tyrrhenian Core.

which was uneventful, three days were spent in the harbour of Dover where representatives of the Marine Instruments of London visited the ship and studied the echosounding, which had been out of function for some time. The experiences gained during the cruise led to a very complete overhaul of the instrument and a reconstruction of different parts, resulting in a much improved equipment for our coming deep-sea expedition.

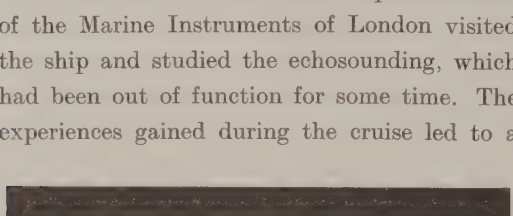


Fig. 21. *Skagerakia Nilssonii.*

On June 18:th the »Skagerak» reached Swedish territorial waters and touched at the harbour of Lysekil on its way to Bornö Station in the Gullmar Fjord, after an absence of 2½ months, the time originally scheduled for the cruise.

The Ways and Means

One of the main deterrents from planning a world-wide deep-sea expedition are the formidable costs involved, and, added to that, the difficulties of obtaining a suitable ship of the tonnage and the great radius of action required.

The city of Göteborg is second in size and in population to the Swedish capital Stockholm, but it takes the first place among Swedish harbours as a centre of shipping and of shipbuilding. Moreover Göteborg has always been renowned for the generosity of its men of wealth and vision towards arts and sciences. When our foremost Arctic explorer A. E. Nordenskiöld planned his expeditions to Greenland and to Spitzbergen in the 1860:s he turned to Baron Dickson of Göteborg for financial backing up and promptly got it. Thirty years later S. A. André, when planning his illfated attempt to reach the North Pole by balloon, also found his main supporters in Göteborg. In the historical introduction to this treatise the generosity towards oceanography shown by leaders of industry and commerce in Göteborg like G. Ekman and K. Mark has already been mentioned. K. A. Wallenberg in his decision to support the Gullmar Fjord research stations on Bornö and in Lysekil was adviced by the landshövding of Göteborg O. v. Sydow, at that time president of the Svenska H. B. Kommissionen. When later Wallenberg decided to bequeath to the R. Society of Göteborg the large sum required for building and equipping Oceanografiska Institutet his chief advisers were

Fig. 22. Major H. JACOBSSON.

Fig. 23. Landshövding M. JACOBSSON.

members of the BROSTRÖM family in Göteborg, especially Major H. JACOBSSON.

Fortunately for our project Major JACOBSSON, at that time president of the BROSTRÖM Combine, was keenly interested in the sea and in deep-sea research. Discussing with him at an early stage our plans we were assured of his enthusiastic support. Not only did he elicit for us a generous offer to utilize for the expedition the new traning ship of the BROSTRÖM Combine the motor-schooner »Albatross» of 1 450 tons, but also permission to have it fitted out with laboratories, workshops, cabins, and other accomodation for the science-and technical staff. In addition to this Major JACOBSSON and his wife, née BROSTRÖM, made a large donation of 500 000 kronor, the equivalent at that time of 130 000 dollars, towards the costs of the expedition.

Fig. 24. Mrs. KARIN JACOBSSON.

Fig. 25. Mr. G. WERNER.

Another promoter of our plans to whom our debt of gratitude is very great, is the successor of v. Sydow, Landshövding Malte Jacobsson of Göteborg, philosopher, statesman and organizer of great efficiency. As president of the governors of our University and of Svenska H B Kommissionen, as well as of the Board of Oceanografiska Institutet, he was indefatigable in promoting our project and in making his influencial friends interested in the planned cruise. Largely thanks to his recommendation the greatest textile magnate of Göteborg, Mr Gustaf Werner promised me, after an interview in the beginning of January 1942, to bequeath 1 000 000 kronor to our R. Society of Göteborg, thus affording it means of sponsoring the cruise.

Thanks to these two major donations the finances of the cruise appeared to be secured. However, the furnishing of the ship and the equipment on board proved to be much more expensive than we had anticipated. Here again Landshövding Jacobsson intervened in our favour and elicited a promise from a magnate of shipping and industry in Stockholm, Consul-general A. Axelsson Johnsson, owner of the Lindholmen shipyard in Göteborg, where the Albatross had been built, to grant us a considerable reduction in the estimated costs.

Amongst other favours obtained, thanks to Landshövding Jacobsson, was a permission for me from the University of Göteborg to have 18 months leave from the chair in oceanography with retained salary, for preparing and conducting the cruise. Also from Svenska H B Kommissionen he obtained similar permissions of leave for Drs Kullenberg and Jerlov, both at that time assistants to the Kommission.

Without help from the men here mentioned it would scarcely have been possible for us to realize our plans for a circumnavigating Swedish Deep-Sea Expedition at the most propitious time for such an enterprise. Had the expedition been delayed for only a couple of years, say by waiting for a government grant with all the preparatory work this would have involved, the rising costs would have made a full-scale realization of the scheme hazardous, if at all feasible.

Planning a Circumnavigating Cruise

The main purpose of the Swedish Deep-Sea Expedition was the investigation of the deep ocean floor, its morphology, its sediment-layers and the thickness of the latter by means of seismic methods. In addition to this was the study of the supernatant water strata, especially those close to and in interaction with the sediments. Further the presence of radioactive elements especially of uranium and radium in the sea-water and also their content in the deposit at different levels below its surface. But also submarine daylight and the penetration of its different spectral components into the water and, in addition to this, an investigation of the suspended particles by optical methods. As a secondary purpose came biological studies of the inhabitants of the deep water-layers, especially bottom-living fishes and invertebrates and their extension down into great depths.

This ambitious program demanded a choice of the field of work where optimal conditions for successful investigations seemed probable. The instruments to be lowered down into great depths, especially the corers, were of unprecedented weight, up to 1 500 kgs, and the weight of the steel cable used for that purpose at full length represented a multiple of the same weight. Obviously the safe and rapid handling of such very heavy gear demands favourable conditions of wind and of ocean swell.

Working in high or even in medium latitudes would have reduced the number of days suitable for successful work in great depths to a small fraction of the time at our disposal. Practically all earlier Swedish expeditions had been working in high latitudes, in the Arctic or the Antarctic. Our cruise, on the contrary, was cast for low, equatorial latitudes where optimal conditions

Fig. 26. The »Albatross.»

of wind and of ocean swell and a high visibility could be counted on.

Another reason for this choise was the low engine power of the »Albatross», only 450 HP, which, even in a dead calm without any sensible swell, gave the ship a speed of only 8 to 9 knots. Also the deep ocean floor between the latitudes 20° N and 20° S, especially in the Pacific and the Indian Oceans had been comparatively rarely explored by modern research cruises, which moreover, had generally traversed the equatorial belt on more or less meridional courses. Especially in the Pacific Ocean there are vast areas where the bottom is covered with Red Clay or with Radiolarian Ooze. Both these sediments accumulate at an exceedingly slow rate. There our long corers would have chances of penetrating down to very ancient deposits, formed millions of years ago, and thus affording evidence of happenings in the surface and over the bottom of the ocean in a very remote past.

These considerations decided us in favour of the tropical and subtropical regions of the oceans as our main field of work. On the other hand, sustained and hard work in these latitudes with their warm and moist climate must be expected to cause an extra strain on the staff. For this reason it seemed advisable to me to have the working- and livingspace of the staff airconditioned, in spite of the extra cost in outfit this involved.

Another question which had to be very carefully considered, was the time to be allotted for recuperation in the harbours visited. Having studied the reports from earlier expeditions we arrived at the conclusion, that the proportion between the time spent at sea and in harbours had better not exceed 3: 1 or, at the utmost, 4: 1, especially in the tropics. With 15 months at our disposal for the whole cruise this meant, that the time under way would have to be limited to not more than 50 weeks. Substracting one third for work at the stations and also for Sundays and holidays, and multiplying with an average speed of 7 knots the total distance run by the »Albatross» would have to be limited to about 45 000 nautical miles. The course actually run amounted to 44 000 miles. Obviously for a circumnavigating cruise like ours 15 months could be considered a fair estimate.

There was at first some hesitation as to which direction for circumnavigating the globe should be chosen. The currents and the winds prevailing favoured the westerly route which was also decided on. An unforseen delay in our start, due to technical difficulties met with in fitting out the ship, almost made us change our mind, as the original schedule would have brought us into the Caribbean Sea during the hurricane season. However, by putting off the Atlantic part of the cruise to the last leg of the expedition, we avoided the dangers of passing through the Caribbean at the height of the hurricane season.

Experiences made during the cruise amply testified to the correctness in our choice of the westerly route. For one thing our echograph, which proved very sensitive to adverse winds and swell, but in general worked very well when

we were running before the wind, would have been out of function most of the time on an easterly course. And the undisturbed registering of the bottom profile proved to be almost a condition *sine qua non* for successful coring operations.

The raising of long sediment cores from great depths was one of the main objects of the cruise and had to be specially considered in working out our time schedule. Thanks to the excellent qualities of our deep-sea winch, directed in a masterly fashion by Dr KULLENBERG, the whole operation of rigging out a long and heavy corer, loading it with its weights, sending it down to the bottom and raising it again to the surface, could be carried out in the course of from 3 to 4 hours when the depth was about 5 000 metres. An increase in depth of 1 000 metres increased the time required for the operation by less than 1 hour. Since the coring work required full daylight, it was generally not feasible to raise more than one core *per diem*, and the treatment of the core in the sediment laboratory and its subsequent packing as a preparation for cold storage took several hours to carry through. Only in the Mediterranean, where the depths were in general moderate, it was found practical to raise two, three or even four cores in the course of a single day.

Beside the coring operations we also had the accoustic work by means of exploding depth-charges to consider. Also the oceanographic series and the sampling of the water down to great depths had to be considered. This work was especially important, and it had to be intensified when making sections across the Equatorial Current system, especially in the Pacific Ocean, and it was then rather time-consuming.

The time-table worked out on this basis in close collaboration with Mr. CHRISTIANSSON and his staff, for reasons beyond our control deviated in some respects from the course actually followed, which is set out in the chart accompanying this volume. In general we were fortunate enough to keep fairly close to the schedule, no untoward incidents or adverse winds seriously deranging our plans. The average speed of the »Albatross» could be kept close to the precalculated 7 knots, and also the time spent in harbours for the recuperation of the ship's officers, the crew and the science staff. We also succeeded in keeping very close to the scheduled 15 months allotted for the whole cruise. In fact, having started from Göteborg on July 4:th of 1947, we regained the harbour of Göteborg on October 3:d of 1948, one day earlier than according to schedule!

Like means for building and equipping the Oceanographic Institute the donations for financing the Swedish Deep-Sea Expedition were given to Kungl. Vetenskaps- och Vitterhets-Samhället of Göteborg, hereafter called »The Royal Society of Göteborg», sponsoring the cruise. It nominated a special committee »Svenska Djuphavsexpeditionens Nämnd» for organizing and planning the Expedition, under the chairmanship of Landshövding M. JACOBSSON. Its other members were:

Major H. JACOBSSON, vice chairman and treasurer,

Mr. T. E. BROSTRÖM (a director of the Broström Combine),

Professor C. SKOTTSBERG, specialist on the flora of the Pacific islands,

Dr. O. NYBELIN, director of the Natural History Museum in Göteborg,

Prof. HANS PETTERSSON, director of Oceanografiska Institutet with,

Dr. B. KULLENBERG as acting secretary, further,

Director E. TH. CHRISTIANSSON was adjoined to the committee as a consultant on nautical questions.

However, in order to broaden the support of this committee a number of specialists in different sciences were invited and agreed to form an advisory committee:

Professor T. GISLÉN, Lund, for marine biology

Professor A. HADDING Lund, for geology,

Fig. 27. Director E. Th. Christiansson.

Professor W. V. Ekman for dynamical oceanography,

Professor E. Rudberg for physics,

Professor A. Tiselius, Uppsala for chemistry,

Professor W. Weibull of Bofors for the seismic soundings,

Commander G. Blix of K. Sjökarteverket Stockholm for nautical questions,

Dr. A. Wassén of Göteborg for bacteriology and

Dr. A. Ångström of Stockholm for meteorology.

For the valuable advice tended by this advisory board we are greatly indebted.

It seems here to be the right place for acknowledging our very great indebtedness to the Broström Concern and especially to Mr Christiansson for the great help we have received both in planning the cruise and in carrying it to a successful end. Indeed without this excellent help and advice our great task would have been too difficult to carry out. We have also to acknowledge our great indebtedness to the officers of the ship and especially to its captain N. Krafft, for their masterly handling of the ship and for meeting with such goodwill and patience the different demands from the science staff and from the author personally, which were not always easy to comply with.

Our sincere thanks are also due to the different Swedish firms who made it possible to create in record time the equipment of the »Albatross» and convert her from a freighter into a first class research vessel. Here the main credit comes to the Lindholmen Shipyard under Director E. Larsson and his staff, to the Allmänna Svenska Elektriska AB »ASEA» and its staff, who constructed the excellent deep-sea winch used first on »Albatross» and later on the Danish research ship the »Galathea,» to the firm of NOHAB in Trollhättan who undertook the construction of the mechanical parts of the winch, to the Bofors AB, from which we obtained the instruments and explosives used by Weibull and his assistants in our seismic experiments. Also to the British firm of Marine Instruments Ltd in London, who were responsible for the construction of the deep-sea echograph. To Hellefors Bruk from which we obtained one of our steel cables used for trawling and coring purposes and to Wrights Ropes Br:ths in Birmingham, who manufactured the two other steel cables used during the cruise.

We are much indebted to various Swedish firms like Pripp and Lyckholm, Stibergs Livsmedelshandel, Göteborgs Kexfabrik and Hasselblads Fotografiska all in Göteborg and also to AB Marabou in Stockholm for generous contributions to our equipment and to our provisions.

For valuable advice and, in certain cases, also for the loan of instruments we are indebted to representatives of the Hydrographic Department of the British Admiralty, especially to admirals Sir John Edgell and to his successor Admiral G. Wyatt, to the Hydrographic Office in Washington D. C. and to the directors of Woods Hole Oceanographic Station.

Our thanks are also due to the Swedish Forein Office in Stockholm for valuable recommendations to consular representatives of Sweden in harbours visited during the expedition.

List of the members of the scientific and technical staff

Fig. 28. B. Kullenberg.

Fig. 29. Dr. F. Koczy.

Fig. 30. Dr. N. G. Jerlov.

Professor H. Pettersson, scientific leader of the expedition.

Dr. B. Kullenberg, director of coring operations.

Dr. N. G. Jerlov, oceanographer.

Dr. O. Nybelin, leader of biological work (1/6—3/7 1948).

Professor W. Weibull, director of seismic work (4/7—24/8 1947).

Dr. F. Koczy, geochemist, in charge of the echo-soundings.

Fil. lic. G. Arrhenius, geologist.

Dr. J. Eriksson, surgeon and naturalist to the expedition.

Fig. 31. Dr. John Eriksson.

Fig. 32. Fil. Lic. G. Arrhenius.

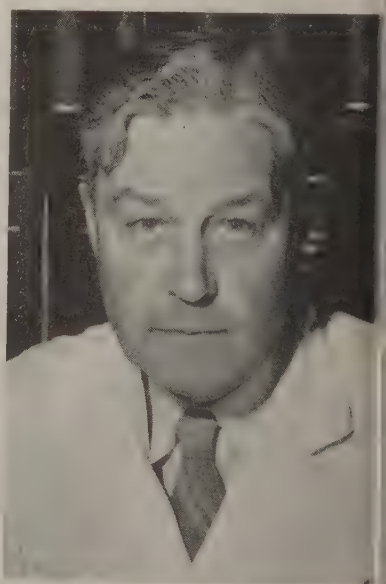
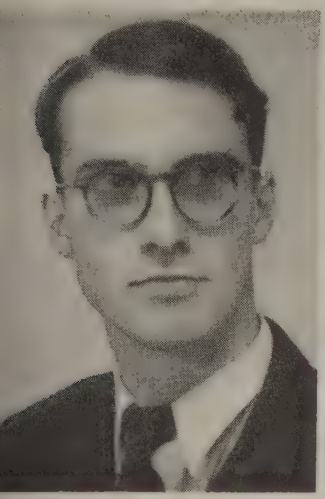


Fig. 33. Dr. O. Nybelin.



ig. 34. Mr. Rutger Pettersson.

Fig. 35. Mr. A. Jonasson.

Fig. 36. Mr. H. Quist.

Mr. L. Bruneau, chemist (4/7 1947—28/5 1948).

Fil. kand. N. Karlsson, chemist (28/5—3/10 1948).

Mr. V. Wentzel, assistant for seismic work.

Mr. R. Pettersson, sediment assistant.

Mr. A. Jonasson, mechanic.

Mr. H. Quist, assistant mechanic.

Fig. 37. Lic. L. Bruneau.

The Atlantic Ocean I

The Start

On July 4:th all our preparations were complete. At 2 p. m. the »Albatross» slipped her cable. Waving goodbye to our friends and relatives, we slowly passed out through the harbour of Göteborg, where all ships saluted us with their sirens, their flags and their cheers. More than half a century had passed since a Swedish Expedition had set out from Göteborg on the high seas, the S. Polarexpedition on board the »Antarctic» under O. Nordenskjöld. Two surviving members from that expedition Prof. G. Bodman and Prof. C. Skottsberg, saw us off. A cheerful luncheon on board, the first repast under way, was enjoyed. Our quarters were duly inspected and found small but adequate.

We had decided not to waste time on the detour necessary for attaining the great deep (700 m) in the Skagerak, but to make straight for our first station to the S of Christianssand on the S. coast of Norway, where the depth is over 500 metres. The echograph was started and behaved very well.

The weather at our start was excellent, in a dead calm enabling the »Albatross» to make

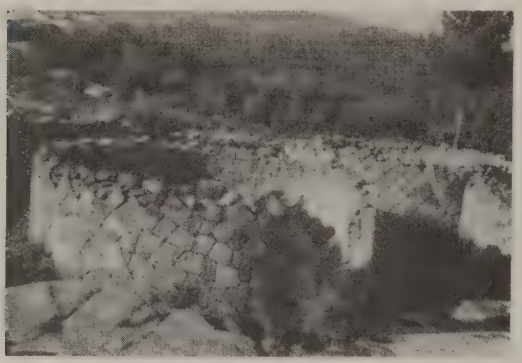


Fig. 38. Pre-Phoenician ruins.

8½ knots. However, before nightfall the sky became overcast and the wind from the SW freshened so that the ship began to heave in the swell, movements which somewhat upset the composure of the young apprentices. In the night the swell increased and the speed fell to only 4 knots. The echograph which had drawn a beautiful double curve yesterday, indicating a thickness of the uppermost deposit stratum, which increased from 15 to 25 metres, now proved highly suspectible to the increased movements of the ship, probably due to airbubbles below the bottom dissipating the energy of the ultrasonic waves. Further observations were therefore postponed until we attained greater depths farther south. Passing along the English Channel, the graveyard of wrecks from ships torpedoed during the war and marked by buoys, was a depressing sight. Late at night on July 9:th we passed Dover, where a year ago we had spent 3 days with the »Skagerak», then returning from our cruise in the Mediterranean. We encountered the Danish research ship the »Atlantide» and exchanged salutes with the flags. She was on her return voyage from a biological cruise off the W coast of Africa.

The main purpose of the work to be carried out in the Bay of Biscay was to afford our English guests, specialists from the Marine Instrument Co of London, opportunities for testing the new echograph in greater depths. Thanks to the wind having veered to the NW we could set sail which improved the speed and steadied the movements of the ship.

On the 13:th of July we reached the centre of the Bay of Biscay. The depth was 4 800 metres which the echograph faithfully recorded. With the attempt to use the piston corer in this great depth we were less lucky. The bottom proved to be hard and apparently free from sediment, which made the corer topple over, so that the lowest 2½ metres of steel tubing were broken off and lost. We were puzzled by the absence of any sediment cover over the rocky bottom, a fact confirmed also by a shot with an ordinary gravity corer, which gave very little sediment but showed the bit damaged by having hit on hard bottom. We found this to be a timely warning, that even in relatively great depths one cannot be sure of a sediment layer being present. This danger calls for precaution in choosing the length of the corer to be used on an unknown bottom. Weibull had also bad luck with his seismic experiments.

A big blue whale blowing repeatedly was sighted, not very far off.

The following day WEIBULL had better luck with his depth-charges which exploded in the desired depth, 2 500 metres and produced echoes, apparently against hard bottom, since there was no sign of a secondary reflexion from a boundary between sediment and rock. In the beautiful weather and an almost dead calm the speed increased to 9½ knots. On July 15:th the Expedition arrived at Leixoes about noon. Our English experts Mesrs SPROULE and SPARLING left us, in order to return by plane to London. Their colleague Mr JEFFREYS staid on board for another few days to attend to the echograph which had so far behaved very well.

Some spare parts to one of our electromotors had been sent after us by plane Göteborg to Lisbon. Our hopes to bring them on board in a few hours proved futile. It proved almost

impossible to make the custom officials in Lisbon release the goods. We had to spend a couple of days idle in the harbour of Leixoes until, with the kind help from the Swedish Legation in Lissabon, the sluggards in the custom office there could be made to realize that we were in a hurry. It was the first, but by no means the last time that we were confronted with the phlegmatic temperament of the southerners, from which the catch-word »manana», i. e. to-morrow, accompanied by a shrug of the shoulders comes so naturally.

We on board utilized this enforced delay for sightseeing and under the guidance of the Swedish vice-consul Mr MORTENSEN some of us made an excursion by car along the coast towards the north. We visited a famous sanctuary called Vania el Castelo and also inspected some ancient fortifications reputed to be of pre-phenician age. We also seized the opportunity for laying in a stock of port to fortify us against coming vicissitudes on the high seas.

From Leixoes to Funchal

Between Cape S Vincent on the SW coast of the Iberian Peninsula and the Canary Islands the ocean floor presents a series of highly curious formations. See the map in Fig. 30 reproduced from G. SCHOTT's excellent »Geographie des Atlantischen Ozeans» (SCHOTT 1926).

A number of submarine banks there rise up from depths of 3—4 000 metres quite close to the ocean surface. The steepness of their slopes occasionally exceeds 20°, i. e. comparable with those of Mount Vesuve or of Fujiyama. The flat summits of the banks have minimum depths of about 150 metres or even less. The discovery of the Seine Bank in 1882 was due to the telegraph cable from Lisbon to Madeira having happened to be laid out over its steep slope, which caused ruptures of the cable. Two cable ships were sent out to investigate

Fig. 39. The ocean depths off Gibraltar.

the bottom configuration systematically, which led to discovery of the bank.

In June 1946, when returning from our Mediterranean cruise with the »Skagerak» we had spent two days investigating the Josephine Bank, the most westerly of the banks, which was discovered in 1883 by a Swedish naval ship of the same name. We had hoped to collect sediment cores from its slopes in order to obtain data from which the age of the bank might be inferred. Owing to the steepness of the slopes no sediment was obtained.

We had intended to revisit the Josephine Bank with the »Albatross» on our course across the Atlantic Ocean. However, attempts to work our big winch after leaving Leixoes proved, that it was badly in need of an adjustment, which could only be carried out in sheltered water. For this reason we were forced to steer a more southwesterly course, heading for the harbour of Funchal on Madeira. This change of course gave us an opportunity to pass over the Seine Bank, the steepest of all. The surface of its flat summit is only 6 miles across with an area above the 200 m depth-curve of only 50 square kilometers. Also here we had no luck, neither with corings now with seismic attempts, so that we had

Fig. 40. Profile through Seine Bank.

perforce to leave the sediments near the bank and also its rocks unsampled.

The shape of these banks and also the geology of the neighbouring islands lead to the conclusion, that they are volcanic in nature. Violent eruptions from craters on the ocean floor must have raised up steep cones thousands of metres above the bottom, until their summits approached the surface or even rose above it by many hundreds of metres. In the latter case an island was born, in the former case a submarine bank was the result. The abrasive power of the ocean waves afterwards planed down the top of the volcano to a level corresponding to the general lowering of the sea-surface during the glacial periods, when the ocean surface fell by nearly 100 metres, possibly by still more.

Judging from geological investigations on Madeira the volcanic activity may well have continued into late Quaternary Time. At the height of the submarine volcanic activity neighbouring parts of the Atlantic coasts must repeatedly have been visited by gigantic »tidal waves», working havoc along the low coastlands. It is fascinating to speculate on the possibility, that a survival of local tradition about these inundations may have given rise to the phantastic tales of Atlantis, which Platon relates in two of his famous dialogues, »Timaios» and »Kritias». Undoubtedly a close investigation of these remarkable banks and of the surrounding seabottom will give interesting results. Judging from present experience, however, the summits and the slopes of these enigmatic structures are so well scoured by currents, that no vestige of tell-tale sediments are obtainable by means of corers and dredgers. Professor WEIBULL planned a kind of exploding charges (similar to those used for demolishing armoured tanks) for blasting the rocks in the banks. Combining such »Molotovs cocktails», as they were called by the Finnish armies against Russia, with the suction from a vacuum container, fragments from the rocks might be retrieved and submitted to radioactive investigations.

On July 21:st, a lovely morning with only a light breeze blowing over an almost calm ocean, the echograph was drawing rapidly rising curves, heralding the approach towards Madeira. The island itself rose majestically out of the blue sea, adorned along its shores with the brilliant verdure of subtropical vegetation. Coasting past the »Sail Rock» we entered the harbour of Funchal, where we spent three very pleasant days.

Funchal has repeatedly been visited by scientific expeditions. Captain James Cook brought his »Resolution» into its harbour in July of 1772 when he was starting on his famous second expedition to the Pacific Ocean, in the course of which he definitely dispelled the fable of a gigantic »Terra Australis», the perennial dream of earlier investigators. According to local tradition Cook at this visit planted a tulip tree, to which we paid due homage. Equally impressive to us oceanographers were the remains from the first tidal gauge, constructed a century later on the initiative of Lord KELVIN, when he visited Madeira with his yacht. He there found his wife, Lady KELVIN, neé BLANDY. A nephew of hers, Dr. GRABHAM, a wellknown geologist, whom I had met before in London, took us in charge and brought us to various sightseeing spots both in Funchal and higher up on the island. We were also taken to the famous wine cellar of the House of BLANDY, where we sampled the vintages of 1792, 1806, 1826 and 1834.

We were allowed the privilege of visiting the magnificent botanical garden belonging to the House of BLANDY. Another most interesting sight was the market hall for fish, where the delicious mullets and the formidable

Fig. 41. The »Albatross» at Funchal.

ooking scabbard-fishes and other exotic in-
nabitants of the deep waters round the island
vere offered for sale.

In the meanwhile our Chief engineer, Mr ENWALL, and his staff together with KULLEN-BERG and JONASSON had readjusted our big winch provisionally, so that it could be used on our first transatlantic crossing. The definite adjustment had to be postponed until a later occasion, when we could get assistance from a well-equipped mechanical workshop.

On July 24:th, a brilliant morning, in an almost dead calm we left Funchal and our kind friends there. Following a westerly course the »Albatross» steered for Martinique in the West Indies, our next port of call. According to our time-table we were to touch at Fort de France not later than on August 9:th in order to have a chance of passing through the Caribbean Sea before the season of the

3

tropical storms culminated there in the latter half of the month.

From Madeira to Martinique

The region between Madeira and the West Indies has not been much frequented by deep-sea expeditions since the beginning of the century, when the Prince of Monaco worked there, making celebrated investigations both in bathymetry, physical oceanography and deep-sea biology.

The German »Meteor» Expedition made no transverse section north of the 20:th northern parallel. Several attractive problems were there for the »Albatross» to investigate. The details of the bottom configuration were very little known. There was the special problem of the »Monaco Deep» at N 30° 46′, W 25° 23′, where the depth sounded is stated to have been nearly 6 300 metres. However, neither

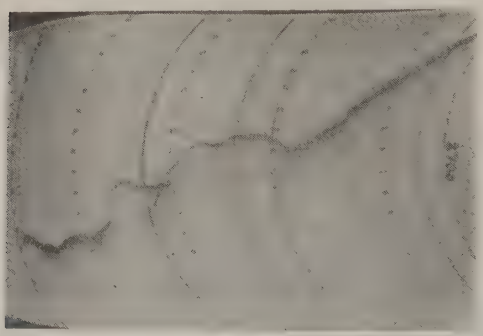


Fig. 42. The rising depth-curve.

the recent charts of the British Admiralty nor the depth tables published in Germany show any depths in the region approaching this high value.

Favoured by excellent weather we found our echograph drawing beautifully distinct and detailed curves down to depths approaching 6 000 metres. Only when we tried it running against the wind the records became blurred and practically illegible, no doubt due to airbubbles getting below the ship's hull and interfering with the ultrasonic beam.

This variegated bottom profile came as a great surprise to me, since I had been expecting very smooth contours in great depths, where the sedimentation, presumably acting undisturbed for millions of years, might be expected to have largely obliterated an original roughness of the bottom. Instead the echograms showed differences in level by as much as 100 metres or even more with a width of a couple of kilometres. Quite often there were instead isolated hills or hummocks jutting up by 50 to 100 metres above the level of the surrounding bottom.

This experience we found repeated all along our course. Perfectly plane and smooth areas extending for hundreds of kilometers were rather an exception than a rule, even in very great depths. This rugged structure of the deep sea floor presented obvious complications to our coring work as also later, in our biological investigations by hauls with the trawl or the dredge. A long corer happening to descend on a steep slope is likely to topple over and descend on the bottom in a more or less horizontal position, when it easily becomes broken or even lost. We, therefore, found it necessary, whenever possible, to survey the region of the bottom near the place where coring was planned, and only when such a scrutiny had reassured us of our chances of getting a good shot, was the corer sent down. Notwithstanding this precaution accidents were not infrequent, especially where a strong surface current or a freshening of the wind made it difficult to keep the ship laid to in a fixed position. Frequently it drifted from a relatively smooth bottom over to hummocks or scarps, before the corer had had time to reach the bottom. The excellent echograph we had on board, therefore, proved indispensable to this kind of work.

On July 27:th we steered a westerly course along latitude 30° 46′, trying to find the great depth marked in the Monaco map for the »Fosse de Monaco» (6293 m.). Although we followed the latitude indicated for almost 20 nautical miles, from W 25° 08′ to 25° 27′, our echograph nowhere recorded adepth exceeding 5 500 metres, i. e. about 800 metres less than the maximum depth ascribed to the Fosse de Monaco. We, therefore, were forced to assume that the depth in question is spurious, at any rate it does not exist near the latitude N 30° 46′[1]).

[1]) For the following information I am indebted to Commandant J. Rouch, director of the Musée Océanographique, and to Commandant Beckert of the Int. Hydrographic Bureau.

The Fosse de Monaco, apparently given that name by Sir John Murray in honour of Prince Albert I of Monaco, was repeatedly visited by the Prince from 1897 to 1912, who never reported deeper soundings from there than 5 530 m. Also from a much later visit with the »Theodore Tissier» in 1936 Dr. Belloc did not report a greater depth than 5 400 metres. The great depth, still retained in the latest edition of the Monaco Map, is due to a mechanical sounding made from the USS ship »Dolphin» in 1889 and reported in Notice to Mariners, N:o 45, Washington 1889. It is this latter sounding, since then unverified, which we consider to be erronous.

On July 24:th the new-repaired winch was gain tried, not without some trepidation. 'ortunately it worked fairly well and the 0 m long corer was safely brought on board om a depth of 4 000 m. Evidently the corer aded with weights to a total of 600 kgs had ncountered a more resistant sediment than nticipated. The length of the core, which onsisted from almost white Globigerina Ooze, as only 165 cms.

The first completely successful coring was arried out on July 27:th at N 30° 46′, W 25° 25′ a depth of 5 400 metres. This time the orer, length 10 m, total load 860 kgs, sank ompletely into the deposit, so that 14 lining ubes were filled with white calcareous ooze. he KULLENBERG corer had proved its worth, aising from a great ocean depth, a core more han 3 times longer than the previous record ength! This excellent result was duly celebra- ed at dinner with a toast to KULLENBERG and o his faithful helpmate Mr JONASSON.

Another still longer and more remarkable ore was raised on July 30:th in a more westerly osition, N 26° 25′, W 34° 00′. From a depth f 5 400 metres a 12 metres long core, consisting f typical red clay was brought up. Only near s upper end one section consisted of Globige- ina Ooze. The first time a sample of the, reviously unknown, red clay had been raised om ocean floor was from HMS »Challenger» n Febr. 21:st 1873, 500 nautical miles to the W from Teneriffe. It is characteristic of very reat depths, and is rarely found in less than 000 metres. Its prime feature, besides the olour which is generally brick-red in the N tlantic, due to ferric hydroxide, and choco- ate-brown in the S. Atlantic Ocean and in the acific, due to an admixture of peroxide of anganese, is its low content of carbonate of ime. Evidently the calcareous shells, which ettle down over the ocean floor from the plank- on organisms in the surface layers, have been emoved from the red clay through the solvent ction exerted by the bottom water. Most

Fig. 43. The piston corer is taken on board.

oceanographers still incline to attribute this solution of lime to the cold Antarctic bottom current, with its high content of carbon dioxide. According to this explanation, however, it seems doubtful whether any red clay could have been formed during Pre-Quaternary times, when the temperature in oceanic depths is generally assumed to have been several degrees higher than at present, and when the lack of polar ice would have deprived the Antarctic bottom current of most of its motive power.

Now, for the first time red clay of undoubted Tertiary Age had been found. For, according to the very low rate of deposition of red clay, one infers, that the lowest layers of our 12 metre core probably became deposited nearly 2 000 000 years ago. This fact seems to support the view put forward by the present author, that a dominant cause of the solution of lime from red clay of Pre-Quaternary age has been the presence in the bottom water not only of carbon dioxide but also of other acids of

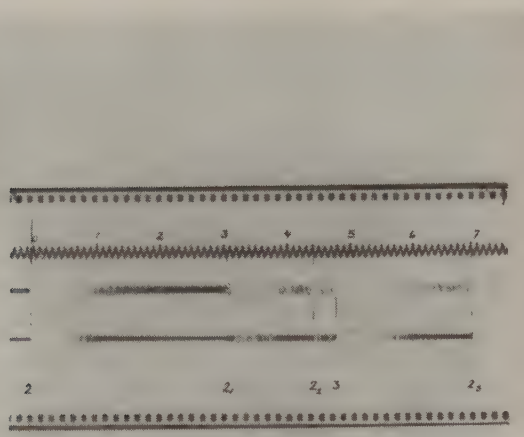


Fig. 44. One of Weibull's echograms.

magmatic origin, due to submarine volcanic action.

On August 1:st we obtained another core of red clay from nearly 5 000 metres which, in addition, contained a couple of small manganese concretions. The origin and structure of these products from the chemistry of the bottom water still present unsolved problems. However, the rate of growth of such concretions, called »manganese nodules» by Sir JOHN MURRAY, who discovered them from the »Challenger», has been determined in Göteborg from radium measurements. The rate of radial growth of manganese nodules from great Pacific depths was found to be about 1 mm in 1 000 years, more on the upper, less on the lower surface. Their occurrence is generally limited to sediments of a very low rate of accumulation, especially to different varities of red clay.

On August 2:d another long core was raised from a depth of nearly 6000 metres. The sediment was here much lighter in colour, due to a higher content of calcareous shells. It contained cavities, probably left by mud-eating organisms, burrowing in the uppermost layer of the deposit. The possible effects from such mud-eaters in disturbing the stratification may prove to be a serious complication in deciphering and dating the »protocols of the deep».

On the following day, Sunday the 3:d of August no coring was done. The echograph drew interesting curves with series of rising »steps» on the slope leading to the summit of the Midatlantic Ridge, which was here found at a depth of 1577 metres, nearly 200 metres less than the lowest figure set out on the charts. Attempts were made to run the ship on a course against the wind. They gave unsatisfactory results with nearly illegible curves, due to the disturbing influence of the ships movements and to airbubbles beneath its bottom.

On August 4:th a corer of a shorter length than usual, 5½ metres, was used. This precaution was amply justified, since the bit of the corer was found to be damaged, probably by hitting on hard rock. The total length of the core obtained was correspondingly small, only 2 metres of whitish Globigerina Ooze.

On August 6:th when we had already passed the Ridge and entered the western Atlantic Valley, meeting with increasing depths, the first large-volume (25 litre) water-sample for radium analysis was raised from a depth of 4 900 metres as well as from higher levels. To each flask 75 cc of hydrochloric acid was added and in addition 2 grams of practically radium-free chloride of baryum. The heavy precipitate of sulphate of baryum formed with the sulphate ions in the water, which contained all the radium present in the sea-water, was separated from the water and brought on to a filter paper, pending future radium measurements in Göteborg.

The echogram on this morning showed a disturbed bottom profile which, however, later in the day changed into a remarkably smooth curve in a depth of 5 600 metres, offering opportunities for seismic work, which were promptly seized by WEIBULL who obtained excellent echoes.

Coring operations on August 7:th were also

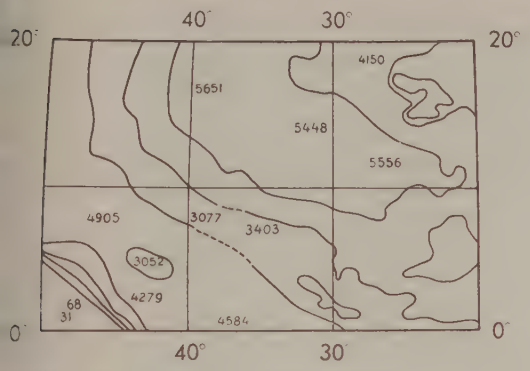


Fig. 45. Part of the Central Atlantic ridge.

successful. KULLENBERG used a 15 metre long coring tube with a total load of 1 500 kgs. The sediment, Red Clay, was so tough, that only 12 metres of the corer sank down into it. Detaching the corer from the bottom proved a most difficult operation. In spite of this the whole coring work was successfully carried out in the course of about 4 hours, a very fine performance which promises well for our future operations, when the time factor will be most important.

The seismic work during the Transatlantic crossing, directed by Prof. WEIBULL, gave interesting results, although complications due to an irregular bottom profile often were serious and not infrequently made the recorded echoes difficult to distinguish and to interpret. The first successful shots were made on July 27:th at the positions N 30° 46′, W 25° 15′ and N 30° 46′, W 25° 25′, i. e. with a distance between the two shots of about 10 nautical miles, the water depth being there nearly 5 400 metres. In both cases triple sub-bottom echoes were recorded in the following depths below the sediment surface:

1 550 m, 2 200 m, 3 475 m and
325 m, 550 m, and 2 400 m respectively.

The large differences between the results from two neighbouring localities are presumably due to differences in level between different parts of the rocky substratum, differences which have been smoothed out by the superposed sediment layers.

That there are at least three different reflecting boundary surfaces in each place indicates considerable differences in the accoustic properties of the three layers, of which the lowest in each case is presumably the rocky substratum.

It should be emphasized here, that the above figures (taken from WEIBULL's paper in vol. IV of these reports, 1955) have been worked out under the assumption, that the velocity of sound in the different strata was equal to the velocity in seawater. This assumption has, so far, not been verified through actual experiments on the velocity of sound in deep-sea sediments. It would be natural to assume, that the real velocity is from 10 to 20 % higher in the sediment than in water, in which case the figures have to be corrected accordingly. Neglecting for the present this correction, the maximum thickness of the sediment down to the substratum would be nearly 3 500 metres. With a conservative estimate for the rate deposition of Atlantic Red Clay of 7 mms in 1 000 years, the total span of time required for the formation of a sediment layer 3 500 metres thick should be of the order 500 000 000 years. For the follow-

Fig. 46. Origin of the Atlantic Ocean, Wegener.

ing reasons this figure must, however, be regarded as a *lower* limit:

a) the velocity of sound ascribed to the sediment is probably too low; introducing a correction of say + 15 % would increase the total thickness to 4 000 m.

b) the effect of »compaction», due to the weight of the superposed sediment layers squeezing out interstitial water, will increase the time factor for the lower strata

c) the present rate of sedimentation is probably much higher than what the average rate has been, especially during the 70 million years of the Tertiary.

On these grounds it seems reasonable to assume a time of at least 1 000 000 000 years, possibly still more, as having been required for the formation of the total thickness of the sediment layers revealed by WEIBULL's measurements.

This results is of great importance, since it affords a decisive argument against the assumption, that these parts of the Atlantic Ocean are of a, geologically speaking, relatively young age, as would follow from WEGENER's famous theory of »continental drift».

Also in the western Atlantic Valley, between the Midatlantic Ridge and Martinique, WEIBULL from two different shots in water depths of about 5 500 m registered sub-bottom echoes. The lower boundary there was found:

at N 16° 21′, W 58° 15′ in 300 m
at N 16° 14′, W 58° 29′ in 300 m

i. e. at about the same depth below the sediment surface as that found for the uppermost reflecting layer in the preceding measurement.

It should be emphasized here, that the failure to detect still deeper reflecting surfaces than those actually recorded, does not imply that such boundary surfaces do not exist, only that the reflexions to which they may give rise are too feeble to be registered with the experimental arrangement used.

It would be most interesting to have these measurements by WEIBULL's reflexion-method checked by means of the refraction-method used by later expeditions.

We felt greaty tempted to spend another couple of days on coring operations in the western Atlantic Valley. However, we were anxious to cross the Caribbean Sea before the height of the hurricane season. Moreover the staff and the crew as well as the officers had had a rather strenuous time during these first weeks of deep-ocean work. In order to give them a well-deserved rest, I felt bound to reach Fort de France on Martinique, our first transatlantic port of call, on August 9:th, which happened to be a Saturday.

We had to console ourselves that the program of our continued cruise implied another Atlantic crossing during the next summer, when we should have new opportunities for probing the depths of the western Atlantic Valley.

From Fort de France to Christobal

In Fort de France on Martinique the »Albatross» stayed for 3 days, largely devoted to sight-seeing, including a visit to the volcano Mont Pelée. On May 8:th in 1902 a violent eruption tore off the top of the mountain, releasing an avalanche of fumes and glowing gas, what the French call »nuées ardentes», which streamed down the steep slope and engulfed the unfortunate city of St. Pierre. More than 28 000 lives were lost, practically the whole population of the town. Destruction also came over the ships in the harbour. It is significant that a series of violent eruptions from a number of other volcanoes in the West Indies and in Central America occurred in April and May of the same year. Thus Quetzatlenango in Guatemala erupted on April 17:th, Izalco in Salvador on May 10:th i. e. 2 days after the Mont Pelée catastrophe, whereas on May 7:th the volcano Soufrière on the island St Vincent also had a violent eruption.

Fig. 47. Dr. PHLEGER and his plankton nets.

One of our purposes with the visit to Fort de France was to take on board our American guest, Dr FRED PHLEGER from Amherst College[1]) in the U S A, a specialist on plankton organisms, the *Foraminifera*, which form an important part of the calcareous ooze in many of our cores. Dr PHLEGER had volunteered to follow the »Albatross» on her cruise through the Caribbean in order to study our methods and to sample for »Forams» the cores raised there, samples which he undertook to analyze after his return (PHLEGER, 1948). His flight to Martinique as well as his return flight from Christobal, where he left the ship, was in every way facilitated by the U S Navy, whose Office of Naval Research took a keen interest in the Swedish expedition.

Dr PHLEGER had been staying with the American consul in Fort de France, Mr HUNT who, together with Mrs HUNT offered us a charming hospitality.

On August 12:th the »Albatross» left Fort de France and took a westerly course through the Caribbean Sea. This »mediterranean sea» of the Central American waters is characterized by the great contrasts presented by its submarine features. Very deep basins, separated by steep submarine ridges make the impression of a lunar landscape.

Our first core was taken off the harbour of St Pierre where, according to a report received from the British Admiralty, a cable ship had foundered at the outbreak of Mont Peleé, possibly through suction from a volcanic vent

Fig. 48. PHLEGER in action.

[1]) Now since several years Professor at Scripp's Oceanographic Institution in Lajolla, Calif.

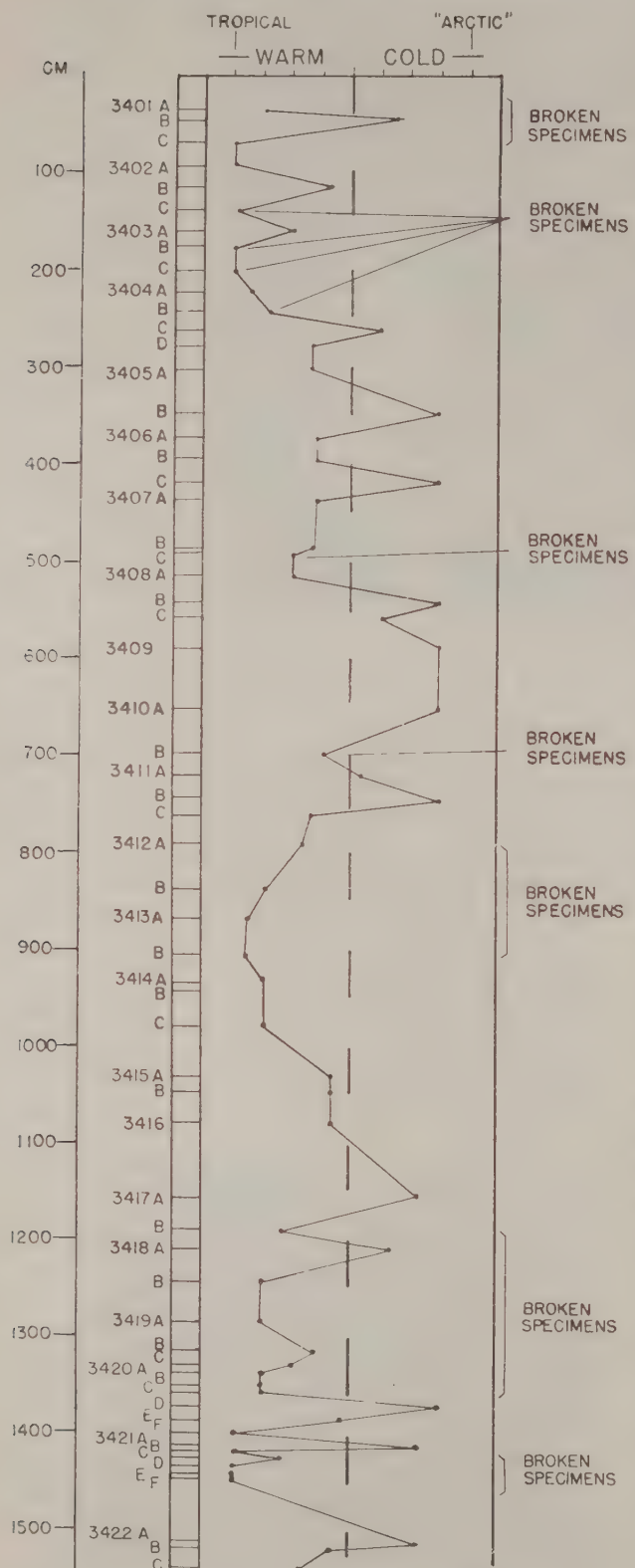


Fig. 49. Forams from the Caribbean, PHLEGER.

which suddenly opened in the bottom of the sea. The core obtained was only 3 metres long and consisted largely of sand but showed no signs of volcanic products, neither ash nor pumice.

During the night the echograph drew a highly irregular curve. The second Carribean core was taken with a corer only 5½ metre long, as a safeguard against this treacherous bottom.

Our American guest Dr PHLEGER had an opportunity to test his excellent plankton nets, which were attached to the ordinary hydrographic sounding wire in different depths, from which the plankton were sampled. Then JERLOV made measurements of the water transparency in the surface layer after having measured the submarine daylight about noon, both measurements gave excellent results.

On August 14:th KULLENBERG made a shot with a 15 metres corer which came up filled with mud of a greyish-green tint, probably coloured by glauconite. However, the winch displayed threatening symptoms and struck work when there were still nearly 5 000 metres of cable out. To our great relief the corer was finally safely brought on board.

Core 34 raised at N 14° 25′, W 65° 55′ which had a length of 15.4 metres was sampled on board by Dr PHLEGER and analysed for forams after his return to Amherst College. The results gave striking evidence of strong climatic variations in the past affecting the composition of the foram shells. They are set out here in figure 40, reproduced from a paper published by PHLEGER in Meddelanden från Oceanografiska Institutet n:o 16 of 1948, i. e. before the expedition had returned to Göteborg. Eleven obvious shifts to cold water faunas have been recorded, and it is possible that even more would have been discovered, if the sampling had been more detailed. It is apparent that the times of colder water were associated with the various glacial stages of the Pleistocene. It is not possible at the present time to inter-

pret with certainty this sequence of shifting marine conditions in terms of Pleistocene history, since our knowledge of the marine phases of the Pleistocene is scanty. It appears possible, however, that the numerous shifts to cold-water conditions are to be correlated with the various substages of the glacial epochs. It is not possible to determine exactly which substages are represented, but it seems likely that all of them would be recorded and preserved in the faunas contained in deep sea sediments.

The echograph drew a very smooth and flat curve. Weibull promptly seized these opportunities and to his great joy obtained distinct subsurface echoes viz:

N 14° 25′ W 65° 55′ water depth 3 760	200 m	350 m
N 14° 27′ W 66° 13′ water depth 5 030		400 m
N 14° 25′ W 66° 26′ water depth 5 060	350 m	450 m
N 14° 15′ W 70° 36′ water depth 4 060	650 m	950 m
N 11° 34′ W 78° 41′ water depth 3 580	150 m	

The depths below the sediment surface of the reflecting layers are seen to be of the same order of magnitude as those found in the open Atlantic Ocean, except that no such great depths as those maxima found in the eastern Atlantic Valley were recorded! However, the values in the Caribbean will be seen to be much higher than those later recorded in the open Pacific and Indian Oceans!

As an example of a very level bottom surface we may take the records between N 14° 18′ W 66° 25′ and N 14° 10′ W 68° 08′, where over a distance of more than 10 nautical miles the depth curve did not vary by more than ± 10 m about an average value of 5 011 m. In this respect parts of the Caribbean bottom present an ideal working ground for coring and trawling purposes.

Finally large-volume water-samples for ra-

Fig. 50. Foram shells, Phleger et al.

dium analyses were raised from the depths of 1 000 3 000 and 5 000 metres to which samples the usual chemicals were added.

On August 15:th, as we were busy extricating and packing the sediment-core raised the preceding day, KULLENBERG came into the sediment lab. with the very gloomy news, that the winch was no more in a working condition, so that we would perforce have to abstain from any further coring before reaching Panama, where the winch must be repaired. We, therefore, had an unexpected free afternoon which PHLEGER used for sampling the core taken for foram analyses. On the following day, August 16:th, the echograph started showing an uneven bottom profile but no distinct »steps» nor hummocks with intersecting curves such as we had met with in the open Atlantic. The curve rose from 4 500 metres to 3 300 metres. A passenger had joined the cruise, a white dove alighted on board. She was quite tame and ate from our hands. A hydrographic series with temperature measurements and water samples was taken in the after-

noon. In spite of the fresh wind all went smoothly.

On August 17:th the echograph drew an almost perfectly straight curve gradually rising from 4 000 to 3 900 metres where it remained constant. In contradistinction from the Atlantic bottom that of the Caribbean Sea presents quite long stretches of a perfectly smooth bottom which remains practically level over fairly great distances.

The wind from astern was fresh so that the »Albatross» with her sails made about 10 knots. We began to suspect that we were in for a hurricane, both on this and the following day, August 18:th. In fact a hurricane was actually blowing over the Caribbean but, fortunately for us, quite a distance to the north from our course, so that we only came into its perifereal region, but in the Gulf of Mexico and in Louisiana it made a lot of damage to shipping and to buildings on the shore.

Like the volcanic eruptions the hurricanes are a scourge to the lovely islands in the Caribbean Sea. According to a statistic I was shown in Fort de France there have in the last 200 years been recorded about one major hurricane of catastrophic force every 12:th year. When they are at their worst these »dancing dervishes» of the tropical seas have an irresistible force, laying large buildings in ruins, destroying the crops and leaving devastation and starvation in their wake.

Thanks to efforts made by the Weather Bureau in Washington, cooperating with the U S Navy, a reliable system of hurricane warnings has been established. Intrepid airmen recording the torrential rainfall from the vicinity of the hurricane have flown straight through its centre and survived in spite of tremendous buffeting. As soon as a hurricane is formed in the region between the tropical calms and the trade wind, their usual breeding place, it is given a female name and its course is closely observed with wireless warnings sent out every 3:d hour. Thanks to these warnings the population on an island or on the coastlands around the Mexican Gulf, lying in the calculated path of the tempestous lady, can seek refuge in special hurricane-cellars.

Optimists have suggested, that a hurricane might be stopped by means of atom bombs. However, the eminent Finnish meteorologist Prof. PALMÉN has calculated the energy developed by an ordinary tropical hurricane to be equivalent to 2 ordinary atom bombs per minute! This shows how feeble even the nuclear forces released by human beings are, compared to the forces of Nature.

From Christobal to Balboa

Arriving in Christobal on August 19:th in the afternoon we were received by General BERRY commanding the US troops in the Canal Zone, and his colleague Captain JACKSON, commanding the U S N squadron in Christobal, a very distinguished and a very friendly reception. During our week in Christobal, necessitated by the reparation of the big winch, in which we had much help from the naval authorities, we were hospitably entertained and invited to visit an impressive military review.

The Panama Canal is, of course, an important artery of shipping and of naval operations and during the war it had to be heavily protected. We heard rumours that 80 Japanese submarines had been operating in the eastern Pacific during the last war, and that a surprise attack on the Canal from the air had been planned. Nothing, however, happened. In fact the only action taken by the Japanese against the mainland was to send a number of balloons carrying explosives, which drifted across the Pacific Ocean, carried by westerly winds. The damage wrought by these missiles was insignificant.

Our time in Christobal was filled with supplementing our tropical outfit and other shopping. Receiving and answering letters from our homeland also took considerable time. The younger members of the expedition seized the

opportunity for visiting a »corrida», a bull fight, a rather tame amusement, the boys afterwards asserted.

Captain KRAFFT and I had accepted an invitation to lunch with a retired Equadorian diplomat, who had published a book on the Galapagos Islands. He warned us that the government of Equador had recently let loose 50 desperadoes on Albemarle, the biggest island of the group, which we had intended to visit for making botanical collections. The desperadoes were expected to cut each others' throats within a couple of years, but until that had been accomplished the island was not considered a healthy resort, so we were advised to visit instead James Island, which is uninhabited.

We had the great pleasure of entertaining on board the »Albatross» both General BERRY and Captain JACKSON. Our Swedish fare, including herring preserves, other implements of our traditional »smörgåsbord», icecold schnaps and export beer, were greatly appreciated.

To our very great regret both Prof. WEIBULL and Dr. PHLEGER had to leave the expedition in Christobal. WEIBULL for a flight back to Sweden, and PHLEGER to return to his work at Amherst College, bringing along with him the samples from a Carribbean core, which he promised to analyze for forams. Both had been very popular on board and we missed them very much.

On August 26:th »Albatross» passed through the Panama Canal leaving the Atlantic for the Pacific Ocean. Our winch had been repaired, and was again in a working condition and, fortunately, remained so during the rest of the cruise.

In Balboa at the Pacific end of the Canal, we had to pass one day during which we enjoyed the hospitality of the Swedish Consul-general, Mr and Mrs ELLIOT, had our first bathe in the Pacific Ocean and our last glass of »Planter's Punch». On August 28:th, well provisioned and provided with fresh water for a cruise estimated to last for about 6 weeks, we left Balboa, steering for the fabulous Galapagos Islands. Our Pacific adventure had started!

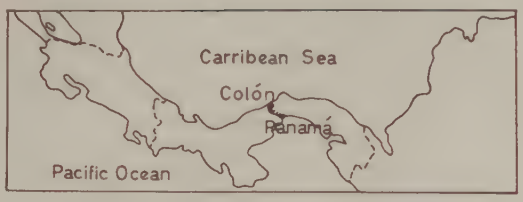


Fig. 51. Map. of Panama Region.

Passing through the Canal we had experienced our hottest spell so far encountered. We then learnt to appreciate to the full the blessings of air-conditioning, against which some of the staff had been sceptical beforehand, fearing that the abrupt changes in temperature would make us liable to catch severe colds and even pneumonia! These fears were soon allayed and after the Panama Canal complaints about the air conditioning, previously an unknown luxury on board a research ship, were only heard when temporary shortage of electric power forced us to turn it off! Whenever northeners are obliged to work hard on the tropical seas, air conditioning in the cabins and laboratories is the best way of ensuring a high efficiency and a good temper of the science staff.

The Pacific Ocean and the Sunda Archipelago

Panama — Galapagos

The Pacific Ocean is not only the vastest of the three oceans, but also the deepest and, in addition, the least explored, as regards its deeper and deepest regions. Here, in the red-clay region along the Equator, we were to meet with the most slowly accumulating of all deep-sea deposits, in which our long corers could be expected to penetrate further back in time than anywhere else. Here we could

Fig. 52. JONASSON with the ring net.

also study the complicated system of equatorial and counterequatorial ocean currents, for which purpose we planned to crisscross over the Equator, sampling the water for its temperature, its salinity, its oxygen content etc. in different depths. Here also we were to put WEIBULL's seismic soundings of the sediment thickness to critical tests in an ocean, assumed to fill the most ancient cavity in the surface of our planet.

Our immediate purpose was to reach the Galapagos Islands in order to study the interesting stratification of the ocean to the south and southeast of the group, and also the character of the sediments beneath this exceptionally fertile region of the equatorial seas. In addition to this we planned to make a landing on one of the islands, in order to make botanical collections of the endemic flora for our great expert on the Pacific Island flora prof. Skottsberg. To our great regret, he had not been able to accompany the »Albatross» to Hawaii, as originally planned.

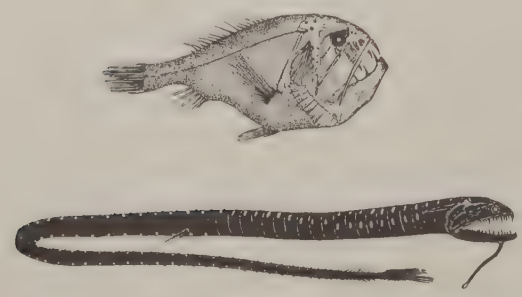


Fig. 53. Pelagic animals from Panama Bight.

On our way towards the enchanted islands »Las Islas Encantadas», as they are called in Spanish, we intended to work both with our plankton nets and our corers, hoping to collect bathypelagic fishes and invertebrate organisms for Dr NYBELIN. Our excellent doctor JOHN ERIKSSON had agreed to act as the »naturalist» of the expedition and to head and direct the biological work, as he later directed the botanical work on the islands which we visited.

All on board took a lively interest in the results from his hauls with a large ring-net towed in a depth of about 1 500 metres. From a quantitative viewpoint the catch was not overwhelming. Still it contained a few transparent fishes, which were eagerly seized on and conserved. I suggested a second haul in only half the depth, or 750 metres. This time the catch was much greater comprising some perfectly black fishes, a considerable number of the beautiful »silver-axes», *Argyropelecus sp.*, a couple of transparent octopuses, three different kinds of *leptocephalids*, larva of eel-like deep-sea fishes, glass-clear heart-shaped *Medusae* etc. Overjoyed with the catch, which ERIKSSON at once started sorting out, we sent a congratulatory wireless message to NYBELIN in Göteborg, who was eagerly expecting news from the expedition.

The echograph had drawn a rather irregular curve showing abrupt changes in depth by as much as 150 metres, not a very promising field for coring operations!

An interesting observation made with the

echograph in the bight of Panama was the presence of a shadowy reflexion, a kind of »false bottom» in a depth generally about 2 to 400 metres, a phenomenon which we repeatedly met with on our continued cruise. We interpreted this shadowy structure, which we afterwards found to vary in depth with the time of the day, rising to near the surface by night and settling to greater depths in daytime, as probably due to masses of plankton or even fishes. During the cruise all echograms showing this layer were labelled »fish». Attempts to catch specimens of these mysterious creatures were unsuccessful.

On our return from our expedition we found that similar observations had been made from other research ships and the shadowy structure had been named »deep scattering layer», but until that time no notice of the same had been published.

August 31:st was a Sunday, so that neither coring nor biological work was undertaken. The surface temperature had decreased distinctly and the air felt cooler, a most welcome change from the sultry atmosphere of the Canal Zone. We were drawing near to the remarkable region of upwelling water from the deep, which is characteristic of the Galapagos Islands. Here, especially to the south and southeast of the group, water from lower levels is brought up to the surface by the currents. It brings along with it, not only a lower temperature but also nutrient salts, which, meeting the daylight, give rise to a profuse vegetation of microscopic algae, phytoplankton, providing nourishment for zoo-plankton and, through them, for fishes. Such an abnormally high fertility of the otherwise relatively sterile tropical surface is characteristic of regions, where water from some depth rises to the surface. Generally the sea surface near the Equator has a temperature of at least 25° C, but in August, when the upwelling near the Galapagos group culminates, the surface temperature may fall as low as to 15° C.

On August 29:th we had a chance for seismic experiments which were entirely successful. In a water depth of 3 115 metres we obtained sub-bottom reflexes from three depths below the sediment surface of 100, 200 and 420 metres respectively, i. e. again a triple reflex like those obtained earlier in the eastern Atlantic Ocean, although here from more moderate depths. Further attempts on the way to the Galapagos Islands did not, however, result in any clear-cut sub-bottom reflexes.

On August 29:th a 10 metres long core was raised from a depth of just over 3 000 metres. The sediment was mud of a distinctly greenish colour with a smell of sulphuretted hydrogen. In the Gulf of Panama the bottom deposit is very rich in organic remains, a natural consequence of its vicinity to shores covered with dense jungles of tropical vegetation. Broken branches and twigs from trees and bushes were frequent additions. Also on the following day another core of 10 metres length was obtained. In this case there had been made an error in adjusting the release mechanism, which did not function before the 5 lowest metres of the corer had already penetrated into the sediment, for which reason the actual depth of the sediment obtained was not well defined. The character of the sediment was much the same as in the preceding core, and the smell of sulphuretted hydrogen was still more pronounced.

Sept 1:st was an unlucky day for coring. Over a depth of 2 700 metres a coring tube 15 metres long was sent down. Extricating it from the bottom proved extremely difficult, probably owing to the unusually tough character of the sediment. Suddenly the cable snapped, so that not only the corer and its content was lost, but, in addition, an 850 metres length of steel cable plus a considerable weight of lead, used for loading the corer. This experience warned us to limit in the future the length of the coring tube to 11 metres, except where the bottom profile happened to

be exceptionally smooth and favourable for coring operations.

On September 3:d the »Albatross» crossed the Equator for the first time during the cruise. The occasion was celebrated by a visit from His Majesty King Neptune (alias KRAFFT) with his attendants, including a charming and very buxom daughter (alias the 3:d mate). In an improvised swimming pool the novices who were crossing the line for the first time, were plunged, after having undergone various ordeals, including a »shaving» by Neptune's chief barber, who used an oversize razor made from wood and a most malodorous soap. Certificates signed by Neptune himself testifying to the baptism were handed over to the victims, after they had recovered from the various abominations they had suffered.

The Galapagos Islands

On September 4:th the »Albatross» reached Chatham Island where we were to report to the »authorities», a very youthful officer who commanded an imposing force of 10 soldiers. He received us very kindly, gave us permission to make a landing on James Island and presented us with a basket full of delicious island-grown oranges. Finally he took us to a bust of CHARLES DARWIN, which had been set up by the DARWIN Society of London in commemoration of his famous visit to the islands from the »Beagle» in 1835.

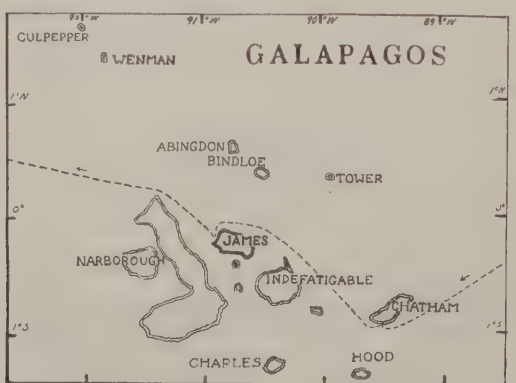


Fig. 54. Map of the Galapagos group.

Fig. 55. Charles Darwin's bust.

CHARLES DARWIN, at that time an unknown young biologist in his early twenties, had been installed on board by the Admiralty as »naturalist» to the expedition, which had started late in December of 1831 from Devonport in England. The main purpose of the cruise was to continue explorations at the southern tip of South America, started during an earlier cruise in 1826. After nearly 4 years at sea the »Beagle» had finished work on the coasts of Chile, Peru and Tierra del Fuego and touched at the Galapagos Islands, until then mainly visited by buccaneers and whalers.

DARWIN was fascinated by the strange flora and fauna inhabiting these volcanic rocks, where almost each island of the group is found to harbour endemic plants and birds developed, as it seemed, *de novo* by the »creative force». From his experiences during the cruise, but especially from his visit to the Galapagos group, DARWIN later developed the train of speculative ideas which, more than 20 years later, were embodied in his famous work »The Origin of Species», revolutionizing the foundations of biological science.

During our short visit to Chatham I made the aquaintance of the American authors, AINSLIE and FRANCIS CONWAY. They had been spending several years, first on James Island and later on Floreana and had fallen in love with the Enchanted Islands.

The AINSLIES greatly regretted having been expelled from this paradise by order from the Ecuadorian authorities. The offical pretext for this expulsion was that their safety appeared threatened by a group of desperadoes, which had recently been let loose on Albemarle, the largest island in the group.

The CONWAYS gave us excellent advice for our landing on their beloved James Island. They have published two very charming books on the Galapagos, which I have afterwards read and greatly admired.

Chatam Island is unique for its postal arrangements. It is the only place in the world from which letters can be sent without postmarks, thanks to the generosity of the Equadorian Government. Nevertheless it must be a source of great regret to philatelists all the world over, that no Galapagos postmarks exist. Publishing and selling a series of such postmarks with strange animals on them would probably afford a revenue to the government sufficent for covering the running costs of administration.

From Chatham Island the »Albatross» followed an easterly course rounding Seymour Island,

Fig. 56. Crossing a lava stream.

Fig. 57. Sea lions on James Island.

on which the US Navy during the II world war had established a wireless station, owing to the key position which the Galapagos Group occupies, relative to the highly vulnerable Panama Canal.

Early in the morning of September 5:th the »Albatross» put five of us ashore on James Island with tents and hammocks, provisions, drinking water, etc. for a séjour meant to last for 5 to 6 days. The ship with our comrades set out for a cruise to the south and southeast of the group, where oceanographic conditions are most interesting, so that both hydrographic and coring work was to be carried out.

In the course of this work two cores were raised, one from a depth of 3 225 metres with a core length of 4 metres, the other one, further west, out of a depth of 3 600 metres with a core length of 5.3 metres. Both cores, according to subsequent analyses made by G. ARRHENIUS, are remarkable for their high content of organic matter as well as of carbonate of calcium, a consequence of the abundance of forams settling over the bottom. The rate of accumulation is high, of the order 4 cms in 1 000 years.

We five, who had been marooned on an

Fig. 58. A lap-dragon.

uninhabited island, passed there six unforgettable days, camping near a small extinct volcano in the midst of giant cactæe and visited by perfectly fearless birds, some of which perched on our shoulders for a friendly chat and also, of a morning, crowded round us when we alighted from our hammocks.

We had happened to land on James Island at the height of the dry season and we accordingly found it a very thirsty place. Also the vegetation was dessicated and rather poor. In spite of Dr Erikssons efforts the botanical collections we were able to make for Skottsberg were not impressive. We had repeatedly to cross over a stream of »pahoehoe» lava, the glassy fragments from which cut our sturdy shoes to pieces and made our wanderings under a nearly vertical equatorial sun rather strenuous. The quadrupeds we met with were mostly goats, donkeys and wild pigs, of which there was an abundance. Much more interesting was the marine life along the shores, which were a santuary of seabirds and sealions. With the latter we established very friendly relations and occasionally bathed together with them.

It was with real regret that we saw the stately hull of the »Albatross» rise over the horizon on September 10:th, signalling that we had to leave our idyllic island and return to a more civilized state, with water to spare both for drinking, washing and shaving!

The Galapagos Island represent a unique outpost for observing the upwelling water near the Equator and its effects on marine life. It is sincerely to be hoped that the plans for establishing there a permanent oceanographic and meteorologic observatory may be carried out, notwithstanding the difficulties of finding scientific observers willing to spend months if not years of seclusion far from the so-called delights of our civilization.

The setting up of such an observatory would also benefit the attempts, however belated they are, to convert one or more of the islands into sanctuaries for the most unique fauna of birds and other animals which they still harbour but that are now threatened with extinction.

Galapagos to Nukuhiva

According to our plans the »Albatross» was to follow a northwesterly course from the Galapagos Islands, making an oblique section through the Equatorial current system, where the complicated stratification of the water-layers attracted the interest of our oceanographers. Between the two vast equatorial surface-currents, sweeping westwards from the northern and the southern hemisphere, there runs across the whole width of the Pacific Ocean a narrow band of water moving to the opposite direction, i. e. from west to east, the Equatorial Countercurrent. In contradistinction to the Equatorial Currents, which have the trade winds as their motive power, the Countercurrent between them is considered to be due to the slope of the ocean surface from west to east, produced by the accumulation of the surface water off the coast of eastern Asia, due to the Equatorial Currents.

Along the Equator this action from the three currents gives rise to zones of »convergence» and of »divergence», the former zone characterized by surface water descending, the

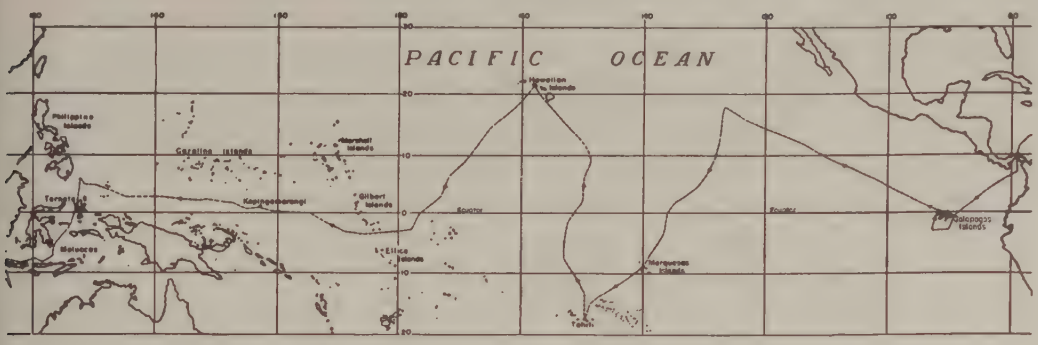


Fig. 59. »Albatross» cruise through Pacific Ocean.

atter zones by ascending water from below. This interplay of different water masses with different salinity and temperature and different content of living organisms, especially of plankton, gives rise to strong variations in the fertility of the surface-layers with corresponding variations in fishlife, which are of considerable economic importance. It was our purpose, by means of frequent observations of the characteristics of the water through hydrographic series, to define the frontiers in the ocean between the ascending and the descending water masses. For this reason our water sampler was sent down from the surface to depths of 1 000 metres and, at intervals, even down to the bottom. The water samples collected were investigated on board for oxygen content and hydrogen-ion concentration, alcalinity, phosphates and silica. The salinity measurements had to be postponed until our return to Göteborg. In addition JERLOV made a study of the optical properties of the water, near the surface by means of transparency measurements and, especially in the deeper layers, by means of the Tyndall method, which he had developed into a very efficient tool of research. (JERLOV 1953)

A special feature of the oceanography in this region is a layer of very low oxygen content found in moderate depths between 300 and 700 metres, with an oxygen minimum in about 400 metres. The reason for this shortage of oxygen is the lack of both horizontal and vertical circulation and the accruement of descending organic remains from the surface layer. Their decomposition through bacterial action leads to a consumption of the oxygen dissolved in the water. In certain localities the oxygen content falls as low as to 0.02 millilitres of oxygen per litre, so that an »azoic» layer is created, in which no animals breathing oxygen can live. This layer must inevitably isolate the populated layers above and below from each other.

For lack of time this layer could not be more closely investigated by means of our large ring-nets, which were very little used during this part of the cruise.

The echograph was kept running day and

Fig. 60. Jerlov measuring submarine light.

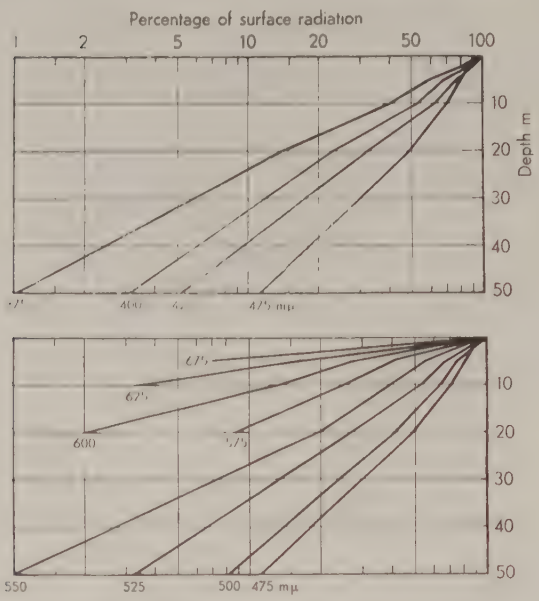


Fig. 61. Percentage of surface radiation at different depths and for every 25 mr. Station 29 in the Carribean sea (JERLOV Vol. III fig. 17, p. 16)

night, save for unavoidable intervals, when the storage cells used had to be recharged. Again, as in the eastern Atlantic Ocean, we were much hampered by the rugged character of the ocean floor, which was highly inimical to coring operations, for which we had to pick out carefully regions of plane or nearly plane bottom.

Owing to this complication the cores raised after leaving the Galapagos Islands were relatively few. Warned by earlier disasters we generally limited the length of the corer used to 5,5 metres only, or, where the bottom conditions appeared favourable, to 10,5 metres. Still accidents did occur.

On Sept. 11:th a successful coring was carried out by means of a 10.5 metre long corer which, from a depth of 2 800 metres, brought up a core 10.2 metres long, i. e. the tube was practically filled with sediment. The bottom profile near the coring station was rather irregular, short stretches of even bottom being intercalated by mounts with an elevation of up to more than 600 metres. The stratification appeared to be strongly influenced by local disturbances of deposition. Calcareous ooze, rich in forams dominated.

Also on the following day a core was raised from a depth of 3 400 metres. However, only one half of the corer contained sediment which, according to subsequent analyses, has undergone considerable postdepositional change. No stratigraphical conclusions could therefore be based on the sequence it displayed.

On September 22:d a most interesting core was raised from a depth of nearly 4 100 metres by means of a corer 10.5 metres long. The length of the core obtained was, however, only 6.9 metres, the reason being, that the corer had only penetrated down to a highly resistant layer through an upper sediment, overlying a rapidly deposited basal bed. This was built up from a layer of gravel of superficially weathered glass together with clay, glass-breccia in clay, with a great quantity of suspended grains of weathered glass. The lower part of the stratigraphically normal clay is rich in phosphates, manganese nodules and reduction bodies. The basal layer, 5 cm thick consists entirely of gravel of black glass. On the whole the deposit is rich in manganese nodules. ARRHENIUS, from whose dissertation this description is taken, adds, that this core was apparently raised from a bed of volcanic acitivity and that the basal bed seems to have been deposited very rapidly possibly in connection with one or more eruptions.' (ARRHENIUS 1952)

Assuming the uppermost 6 metres of clay deposit to have accumulated at an average rate of 1 cm in 1 000 years, the age of the volcanic layer, which must have undergone a much more rapid deposition, should be about 600 000 years. This estimate is, of course highly approximate and represents, in all probability, an underestimate of the real age. That the volcanic layer comes from adjacent submarine volcanoes is the most likely, since the nearest islands, the Clipperton

slands, are about 150 miles away and are not olcanic in nature.

The abundance of manganese nodules in his core is of interest, as it speaks in favour f a volcanic origin of the manganese.

September 23:d was a very black day for ur coring operations and for me personally. n my eagerness to test the wide—bore corer which had been made specially for obtaining naterial from the ocean floor for the extraction of magnetic spherules, I had it mounted at the end of our long wire, although this had recently been spliced and was, therefore, not considered quite safe. To my dismay the cable snapped at the splice and the corer was lost, the only one of that type we had on board! It took three months before a new corer of the same wide bore could be manufactured in Honolulu and the first time it was used with success was on the 30:th of December. It was then sent down in the western Pacific to a depth of 4 800 metres and came up filled to its full length, 5.6 metres with red clay, mixed in its lower levels with Globigerina Ooze. But in the central Pacific, between Papeete and Honolulu, where thick cores would have been most interesting to study, only the ordinary, 46 mm corers could be used.

The snapping of our cable necessitated an exchange of the broken cable for one of our spare cables of British make. It had to be very thoroughly oiled, as a safeguard against corrosion. It proved to be 500 metres longer than we had anticipated, 8 000 metres instead of only 7 500 metres. It gave excellent service, so that it lasted us for the whole rest of the cruise and we brought it back to Göteborg in good working condition, without any need for using our third (and last) spare cable!

Thanks to the rapidity with which the replacement of the cable was carried out under KULLENBERG's supervision, he was able to take a shot with a 10.5 metre long corer already on Sept. 26:th when a core 9.7 metres long, consisting from light greyish-yellow clay was raised from a depth of 4 300 metres. Considerable amounts of colloidal silica were present and, in addition, the upper parts of the core displayed frequent traces from mud-eaters, which had delved in the deposit.

The sudden illnes of the youngest of our apprentices caused us all, and especially Dr ERIKSSON, considerable anxiety these last days. We apprehended that it might become necessary for us to run straight to Honolulu to put him ashore. As he got worse ERIKSSON found it necessary to operate on him, removing a deep suppuration near the femur. The operation went well and the boy's health improved rapidly. Had we not been fortunate enough to have a skilled surgeon on board, we would have been forced to radical changes in our plans for the continued cruise. Moreover, it seems doubtful whether the boy would have survived the transport to Honolulu.

Our oceanographers who had been working very hard with their bathygraphic series and their water samplings, urged us to continue on our northwesterly course, instead of running southwards as originally planned. I agreed to give them an extra two days, in which the northern limit of the equatorial current system, a most interesting region, could be reached. With complete satisfacation to them — and to ourselves — we could then, on Sept. 28:th change our course towards the SW. Before that we made an interesting sounding in a depth of 4 230 metres. The usual reaction on the dynamometer, indicating that the corer had reached the bottom, was here very indistinct, so that KULLENBERG, to make sure, allowed the corer to fall freely twice from a height of about 15 metres above the bottom.

The topography of the bottom near the place of corings was highly irregular with a seamount 400 metres high, probably one of a group of submarine volcanoes, rising abruptly from the otherwise flat ocean floor. The corer had been let down quite close to that mount. On inspecting the corer it was found to have

penetrated by about 30 cms into a bed of volcanic material at the first drop and, at the second drop, to have tumbled over and come to rest lying on the bottom. The damaged bit of the corer proved that it had been in contact with a hard bottom which, according to ARRHENIUS' analysis, consisted of rounded nodules rich in clay and holding glass and palagonite. There were also fragments from two, possibly different, crusts of manganese. The sediment is a fossil-bearing greyish-brown clay, rich in glass and palagonite. Its content of fish teeth is unusually high, up to 6 teeth per gram of sediment.

This core gives indisputable evidence of submarine volcanic action, probably from the mounts recorded by the echograph in the immediate vicinity of the place of coring, assuming these to be extinct volcanoes. The occurrence of manganese as crusts is significant and again lends support to the view earlier expressed, that manganese on the ocean floor in higher concentrations, either as nodules or as crusts, is of volcanic origin and not primarily due to an accretion from seawater. Contrary to the volcanic basal layer in the core raised on September 22:d this new evidence of volcanic activity, judging from the thin sediment layer above the manganese crust, indicates a comparatively recent eruption, presumably in late Quaternary Time, perhaps even of post-glacial age.

It would be tempting to suggest that these two instances of submarine volcanic activity have some relationship to the great fissure in the earth's crust, which has given rise to the Hawaiian Islands and to the submarine lava beds in their vicinity. However, the two localities here mentioned are situated at a considerable distance to the NW from the prolongation of the main line of fissure. In any case, they testify to independent centra of submarine volcanic acitivity in the northeastern part of the Pacific Ocean.

Another remarkable core with the corenumber 53 was raised on Sept. 29:th from a depth of about 4 750 metres. The length of the corer was again 10.5 metres, but the length of the core obtained was only one third of this or 3.5 metres.

According to subsequent analysis the core represents a truncated sequence consisting of Tertiary chalk — ooze and clay. The missing top is believed to correspond to at least 10 m of Pleistocene and late Pliocene clays and an unknown thickness of older calcareous deposits. It is not known with certainly whether the truncation was caused by slumping, i.e. by a submarine landslide, or by gradual current erosion.

This core was the first instance we met with of severe postdepositional changes in the sediment, laying bare much older strata, which had presumably been overlain by thick layers of more recent deposits.

From the data quoted from ARRHENIUS he concludes, that core 53 is confined upwards by a surface of abrasion or of nondeposition. Against the latter alternative ARRHENIUS quotes the fact, that bottom currents strong enough to be capable of extensive erosion have generally not been considered to exist in the Pacific. The mechanism which caused the uncovering of the Tertiary subsurface deposits in this core must, therefore, be regarded as not quite clear.

Further on in this Report we shall find more examples of such older sediments of Tertiary Age, lying uncovered in the sediment surface.

On Sept 30:th a core No 54 was raised by means of a 10.5 metre corer from a depth of 4 800 metres, the length of the core being 9.7 metres. The main part consists from very light-coloured yellow clay, which is, however, at certain levels coloured blackish brown by finely divided ferric and manganese compounds. Digging structures and reduction bodies due to organic residues are frequent throughout the column.

A most interesting core (No 58) was raised by a 10.5 metre corer on October 4:th from a

epth of 4 400 metres, the length of the core eing 9.9 metres. ARRHENIUS here finds the te of accumulation to have been very low id ascribes an age of 2.5 million years to ie basal layer, which implies an average rate deposition of 4 mms in 1 000 years.

Amongst the following cores the one number- l 60, taken from a depth of about 4 550 metres ith a 10.5 m corer, which had a length of ist over 10 metres, is noteworthy, because it isplays great variations in the rate of a accu- ulation, viz. from 65 mms in 1 000 years in s upper levels, to only 5 mms per 1 000 years i the lower levels. This fact is tentatively ttributed to changes in the water circulation uring the last 700 000 years.

Of the remaining two cores taken on the oute to Nukuhiva both displayed truncated ores. The corresponding loss from the top f the core 61 is estimated to have been about 5 cms, corresponding to a sedimentation time f about 10 000 years. In the case of core 62, he longest one so far raised in the Pacific Ocean, with a total length of 14.8 metres rom a depth of 4 500 metres, it is assumed to each back in time by approximately 1 600 000 ears which would correspond to a rate of ccumulation of about 9 mms in 1 000 years. The missing top is assumed to have had a ength of between 40 and 50 cms, correspond- ng to the sedimentation during about 50 000 ears.

The seismic measurements made on the oute between Galapagos and the 18:th northern atitude gave the following values for the depth of the reflecting layers

Station	Lat	Long	Depth	subbottom reflexes
58	N 01° 04′	W 93° 20′	2 820 m	275 m, 420 m
61	N 03° 20′	W 97° 53′	3 400 m	210
71	N 09° 26′	W 109° 55′	3 780 m	120
86	N 17° 46′	W 126° 51′	4 650 m	650

As is seen from the above table the sediment thickness, as judged from the depths of the sub-bottom reflexes, is only a fraction of that found in the eastern Atlantic Ocean, with the exception of that recorded at Station 86, which is anyhow much lower than the highest values found between Madeira and the Midatlantic Ridge.

The oceanographic series had been conscienciously followed up also on our southern course and gave excellent results, displaying both the lines of convergence and divergence encountered in the equatorial zone. On October 9:th we called a stop, and our oceanographers had a well-deserved rest.

Our water supply was running short, having been on the high seas since we left James Island on September 11:th. It was with considerable relief we saw the romantic contours of Nukuhiva rise against the setting sun in the evening of Oct. 11:th. However Captain KRAFFT considered it prudent to stand by over night off its northern coast. It was, therefore, not until the morning of October 12:th that the »Albatross» made her entry into Taihoe Bay, where we were to make the acquaintance of the island so eloquently described by HERMAN MELVILLE and by ROBERT LOUIS STEVENSON.

Our first long hop in the eastern Pacific Ocean was finished without any serious mishap, save for the loss of my wide-bore corer and several thousand metres of stout steel cable!

Nukuhiva and Tahiti

The Marquesas Islands were discovered already in 1595 by the Spanish explorer ALVARO MENDANA who visited the four southermost islands of the group. In honour of his protector, Marquesas de Mendosa vice-roy of Peru, he called the group the Marquesas Islands. Almost two centuries passed before the islands were again visited by Europeans under Captain COOK who, on his celebrated second voyage into the Pacific Ocean, brought his ship, the »Resolution», to the island Taouata, into the

Fig. 62. Waterfall on Nukuhiva.

harbour called Madre de Dios by his Spanish predecessor. The largest and most northerly island of the group was, however, not discovered before in 1791 by the American explorer INGRAHAM. Six years afterwards the two first missionaries landed on the group. One of them was so appalled by the immorality of the inhabitants, that he almost became insane and hurriedly made his escape on a visiting ship! During the early part of the 19:th century Nukuhiva was repeatedly visited by English, American and Russian ships, but not until 1842 were the islands declared a French »protectorate» and have, with a few intervals since then belonged to the »Oceanie Française».

According to Captain COOK the inhabitants of Nukuhiva were the physically most perfect specimens of manhood he had met with in the Pacific Ocean. The men were courageous, full of fighting spirits and inveterate cannibals. The morals of the women there he describes as almost as low as that of the Tahitian women. Tribal wars raged between the inhabitants of the different valleys, whose total number was estimated to have been well over 10 000 during the early decades of the 19:th century. Infectious maladies, due to contact with visiting sailors, decimated the population so that it dwindled to a small fraction of the earlier number. This depopulation was continued also during the present century. After the world-wide ravages of the »Spanish flue» after the I:st world war, the population of Nukuhiva alone dwindled to less than 1000. Largely thanks to the sanitary measures introduced by the French rulers, there is now an upward trend of the population-curve, mostly due to a greater viability of immigrants from Tahiti and other islands. The old Marquesan aborigines are now almost extinct.

We with the »Albatross» visited Nukuhiva

Fig. 63. Bothanical excursion.

rtly in order to replenish our fresh water, ıich had become nearly depleted after six eks at sea, partly to obtain fresh provisions, t also in order to accord a well-deserved rest the scientific staff, the officers and the crew board.

Nukuhiva was the first larger island in the ıcific Ocean that we had visited and its ınderful scenery and the luxuriant tropical getation growing in its fertile valleys made profound impression on us all.

We were most hospitably received by the rench acting governor Dr LAVAUD and his ıarming consort, of French-Tahitian extrac- on. A delicious »repas Tahitien» was served us ı the loggia of his governmental residence, a ighly interesting series of folk-dancing was rranged for our entertainment and an inter- ational foot-ball match, Nukuhiva-Sweden was rranged between the apprentices from the Albatross» and the youth of Nukuhiva, aptained by the energetic missionary, PÈRE EAN.

Science was, however, not neglected. Dr. ERIKSSON together with KULLENBERG and ARRHENIUS and native guides led an expedi- ion up to the Tovii plateau, where one of the very few peat bogs within the tropical zone is ocated. One of the purposes of the expedition was to enable ARRHENIUS to sample cores from his peat bog for future pollen analytical in- vestigations. Another purpose was to find a »wild banana», reported to grow up on the Tovii plateau, but not previously seen by any bota- nist. In both purpose the expedition was successful.

When it returned, via the fertile Taipi Valley, famous through HERMAN MELLVILES romantic description in »Typee» of his life there, the »Albatross» had left the Taihoe Bay for a visit to the Taipi bight and took the expedition force on board with their collections. Another excursion by motorboat was made to the nar- row and most picturesque Hakui Valley which we followed up to its famous waterfall, a veil of

Fig. 64. Our hostess on Nukuhiva.

silver draped over a chasm of black volcanic rock more than 600 feet high.

With regret we left this wonderful island of eternal summer and set a westerly course for Tahiti.

From Nukuhiva to Tahiti

The departure from Nukuhiva was marked by many touching signs of affection on part of the inhabitants. Dr. LAVAUD and his lady came on board and decorated us all with »leis», garlands of fragrant flowers. Gifts of the most different kinds were showered on us. October 18:th, our first day on the sea, time was de- voted to bring order into and to stow away the collections made by Dr. ERIKSSON and his party. A somewhat uncomfortable souvenir from Nukuhiva for most of us were mosquito bites, with accompanying itch, which it took us several days to get over.

The bottom profile along our course was decidedly rugged and attempts to take cores even with our shortest piston corer of 5.5 metres failed. The bottom was hard, in one case the damaged bit of the corer brought up a fragment of lava and what little sediment

had entered the coring tube mostly disappeared during the hoisting on board. Not until on our fourth day out a rudimentary core 1½ metre in length was obtained with a 5 metre corer.

Experiments with a submarine camera, designed for measuring the intensity of light in greater depths, were made by JERLOV and KOCZY. In a depth of 300 metres exposure of 1 second gave a distinct blackening of the film, whereas in a depth of 400 metres even an exposure 500 times longer gave only an almost imperceptible impression, indicating a change in the transparency of the water-layer between 300 and 400 metres (JERLOV and KOCZY 1951). The program of measuring the ultraviolet subsurface light within the sheltered water inside an atoll had to be postponed, owing to the difficulty of finding a navigable atoll in the Tuamotu or »Dangerous» Archipelago.

Three seismic experiments made under way were successful and indicated sub-bottom reflexes coming from depths below the sediment surface of 150 to 165 metres. They afforded a confirmation of our earlier results in showing that, as far as can be inferred from the recorded reflexions, the thickness of the uppermost sediment layers in the Eastern Pacific Ocean is comparatively small.

Tahiti

On October 24:th the »Albatross» entered the harbour of Papeete, capital of the most famous of all the South Sea islands, Tahiti.

Tahiti was discovered in June 1767 by the English sea-farer Captain WALLIS who, after various skirmishes with the belligerent natives overawed them through the use of firearms. Nine months later the French circumnavigator BOUGAINVILLE touched at the island. The next year a much more important event in the history of Tahiti occurred, when Captain JAMES COOK brought his »Resolution» into the Maravai bight.

The purpose of this visit was mainly astronomical, to establish an observatory on the coast of Tahiti for observing the coming transit of Venus on the 3:d of June 1769. Thanks to ideal atmospheric condition the observations were eminently successful. COOK, however, profited from his stay at Tahiti for circumnavigating the island and surveying its coasts with meticulous care. He was very well received by the natives but their inveterate thievishness, stealing important parts of his equipment and even his precious quadrant, essential for the astronomic observations, involved considerable embarrasment to the work.

The history of Tahiti during the following century is marked by an invasion of missionaries, at first of the protestant faith but, after the 1840:s also Roman Catholics, aided by the high-handed policy of the French emissaries in reducing the independent kingdom of Tahiti to a French protectorate. During the 20:th century there has been a peaceful penetration by Chinese merchants, who have ousted not only the Tahitians themselves but also most other traders from commerce and have acquired considerable wealth. Since they are by law forbidden to buy real estate, they seem to expend their wealth in luxus cars which rush about Papeete and its neighbourhood, filled with contented Chinamen and their families.

We had a charming reception from various inhabitants of Papeete and received much friendly hospitality. The governor himself[1]) had little time for us, being occupied with administrative matter which was perhaps quite as well, since he, at a formal visit, did not make a very congenial impression. We were especially well treated by the officials of the »Societ

[1]) I was told that one of his advisors had urged on him the necessity of arranging a formal reception for the staff and officers of the »Albatross», considering the scientific importance of our mission. To this his Excellenc was said to have replied: »No need to make any fus about these Swedes. We have much more famous scientists in France,» in which he undoubtedly was perfectl right!

es Etudes Océaniennes» in Papeete and enyed visiting their museum.

Dr. ERIKSSON could not resist the temptation f making an excursion up into the mountains the famous lake Vahiria where, according to ıe natives, a large eel provided with external ırs is reported to live. The expedition, although ;renuous, was most interesting, and a lot of ıre plants were brought back, but no specimen f the mysterious eel!

Some of us seized the opportunity of visiting he neighbouring island Moorea, still more icturesque even than Tahiti, where we were eceived with lavish hospitality by Mr and Irs KELLUM, who had been staying in this arthly paradise for nearly 20 years.

Tahiti is a very expensive place, owing to he high rate of exchange, the Tahitian franc eing at the time of our visit equivalent to bout 3 Parisian francs. Also in other ways mmigration is not encouraged and Europeans r Americans who come there in quest of a heap and romantic existence, usually clear ut very soon with empty wallets and their llusions shattered. However, the attraction xerted by the natural beauty (and beauties) f the Queen of the South Seas is still very owerful, as we on board the »Albatross» discvered in our next harbour, that of Honolulu.

From Tahiti to Hawaii

To me personally the planned cruise from apeete to Honolulu represented one of the ıost interesting parts of the whole expedi-ion, especially as regards the bottom condi-ions. Just over 72 years earlier H M S Challenger» left Hilo, the main harbour on he island of Hawaii. Of the following part f the cruise Sir JOHN MURRAY and RENARD rite in the 4:th volume of the »Reports» of he expedition: »An excellent meridian sec-ion was made between the Sandwich and the Society Group. Within one month observa-

Fig. 65. Excursion to Vahiri Lake.

tions were made at 17 different stations in depths varying from 1 500 to 3 000 fathoms. The sediment samples collected comprised red clay, radiolarian ooze, globigerina ooze and volcanic mud. The dredge and the trawl brought up many strange marine organisms, some of them new to science and, in addition, a wealth of so-called manganese nodules, which are curious growths formed in great depths, found together with ear-bones of whales and teeth of giant sharks of Tertiary age. The last-named relics from bygone ages, found in the uppermost layer of the sediment, are a striking evidence of its incredibly slow rate of deposition.»

Many years earlier I had obtained from the British Museum a jar with sediment from »Challenger» Station 276 (lat. 13° 28′ S, long. 149° 30′ W) which contained red clay of two different shades of colour and, in addition, a number of small manganese nodules. Measurements of the radium content gave very high values, up to 20 times higher than for continental sedimentary rocks. The external, i. e.

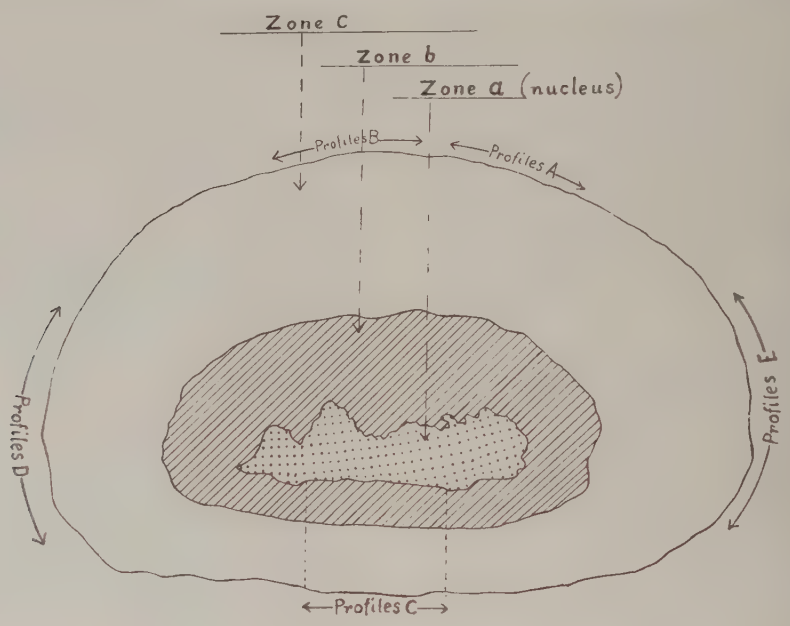


Fig. 66. Vertical section through large nodule.

most recently formed parts of the manganese nodules were also rich in radium and the rapid decline in radium inwards, due to the disintegration of »unsupported» radium, afforded a possibility of estimating the rate of growth at about 1 millimetre in 1 000 years (PETTERSSON 1943).

I now intended to revisit some of these »Challenger» stations and to repeat the sampling by means of a much more powerful technique. Provided my estimate of the rate of sedimentation of the red clay had been correct, our longest cores should bring us back to layers deposited well back in the Tertiary, many millions of years ago.

In the afternoon of November 3:d the »Albatross» left Papeete, where numerous friends had come down to the quay to see us off and decorate us with the traditional »leis». These, also according to tradition, had to be thrown overboard when we left the harbour, thus ensuring our return to Tahiti!

On November 4:th it was blowing too hard to make coring operations safe. On the following day the first shot was made with a corer of only 5½ metres in a depth of 4 600 metres. This time the release mechanism failed, which very rarely happened. Traces of sediment adhering to the outside of the corer proved it to be red clay of dark colour, containing phillipsite crystals. A hydrographic series down to 1 000 metres was taken, and afterwards 4 large-volume water-samples for radium determination.

On the following morning, Nov. 6:th, our first successful coring was done in lat. 13° 25′ S, long. 149° 30′ W, depth 4 625 metres with a corer 10½ metres long. The operation gave a core-length of only 5.8 metres and the bit of the corer had been damaged, an indication of a hard bottom below the sediment probably a lava bed. This was confirmed by the echograph, which near the station drew a double curve, showing a reflecting surface about 3 fathoms below the bottom. The seismic experiments at this station gave subsediment echo from about 135 metres below the sediment surface, indicating the

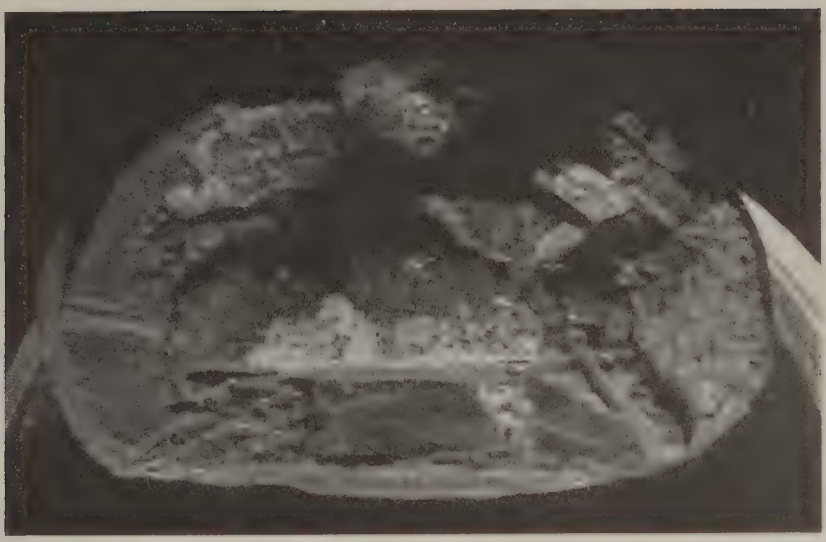


Fig. 67. Vertical section through manganese nodule.

he reflected signals had twice traversed he uppermost lava - layer, and had, presumably, become reflected against a deeper and more compact lava bed or by the substratum.

The upper part of the core consisted from red clay with numerous crystals of phillipsite. In the lower parts, below, 4.6 metres, dark brown layers alternated with lighter ones containing considerable amounts of lime. This stratification became especially prominent in the lower parts of the core, where some thin layers of sand were also found.

Attempts to obtain, by means of our large dredge, manganese nodules from this locality, where the »Challenger» had found such in great profusion, failed, possibly owing to the length of the towing cable not having sufficed for an effective skimming of the uppermost sediment layer.

On Nov. 7:th in the afternoon the big dredge, which had been somewhat modified in order to ensure a greater efficiency, was sent down and towed along the bottom in a depth of nearly 5 000 metres. The result was disappointing. During the haul the »Albatross» had happened to come from a very smooth bottom to one of a rugged character and the dredge had been ruined, most of its parts and especially the netting had been torn away against some obstacle on the bottom. On account of the rugged character of the bottom it was not considered safe on November 8:th to use here a corer of more than 5½ metres length. The length of the core raised, which was very dark brown in colour, was only 4 metres. It contained many crystals of phillip-

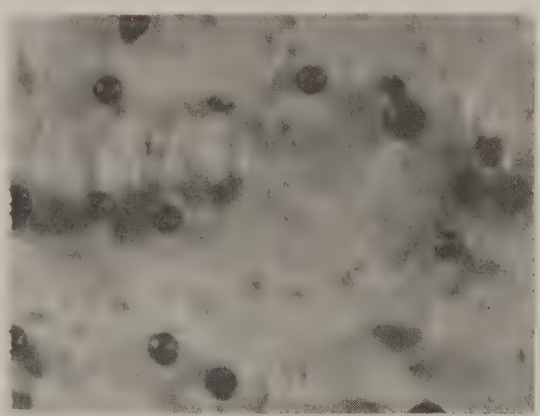


Fig. 68. Cosmic spherules from W. Pacific.

site, small teeth from fish, and mineral grains, showing optical anisotropy, which were presumably of volcanic origin. Measurements of the hydrogen - ion concentration in the sediment gave practically constant values, about $pH = 7.20$, with a slight tendency to somewhat lower values further down.

On November 9:th, a Sunday, no coring was done. On the following day we came close to »Challenger» Station 274 (lat. 07° 38′ S long. 152° 53′ W) depth 4 990 m. The plane nature of the bottom encouraged KULLENBERG to use a 10 m corer, which came up full with dark brown sediment. Without changing our position a second shot was made with a 15 m long corer, which was also successful. The whole of the latter operation was carried out in 3 hours, a quite remarkable feat, demonstrating how efficient KULLENBERG's method of work has become. This core, the longest so far taken in the Pacific Ocean, was remarkably homogenous, testifying to apparently unchanged conditions of sedimentation over millions of years. The water content alone showed a decline with depth under the sediment surface. Measurements of pH gave values varying between 7.09 and 7.15 in the uppermost metre, whereas further down the values fell until a practically constant value of 6.90 was attained.

On November 12:th the next core was raised from a position near that of »Challenger» Station 272 (lat. 04° 04′ S, long. 152° 53′ W, depth 5 200 m). Length of the core 15 m. The colour varied from brown with yellowwhitish streaks in the upper parts to dark brown in the lower regions. Lots of radiolarians were found in this red clay, justifying the designation »radiolarian ooze.» Measurements of pH gave practically the same results as with the preceding long core. One explanation for this structure suggested, was that it might have been caused by »slumping», i. e. through a transport along the bottom of already deposited layers by submarine landslides, possibly started by volcanic eruptions. Another explanation was that mud-eaters, delving in the sediment, had left their marks.

No coring was done on the following day but instead hydrographic series and measurements of submarine light and transparency. Tyndall measurements of the suspended particles indicated a concentration of red particles near the 400 m depth. On Nov. 14:th the first successful experiment was made with the »geothermometer», lowered to a depth of 4 500 metres, where it was plunged three times into the bottom at intervals of about 15 minutes, remaining in the bottom for a total time of 45 minutes, or more than sufficient for the thermometer inside to assume the temperature of the surrounding sediment. Everything had functioned all right and gave a temperature difference between the bottom water and the sediment in 11 metres of +0.51°. This means a geothermal gradient of 1° C for a difference in level of 21.5 metres. This value is unexpectedly high and indicates a temperature gradient considerably larger than the average for the continents, where 33 metres per degree centrigrade is normal. The geothermal heat-flow through the ocean bottom, of course, also depends on the thermal conductivity of the sediment which, owing to its high water content must be rather low. Anyhow the theoretical reasons for assuming a much less intense geothermal flow through the ocean floor than on the continents are not supported by these results, which, from a general geophysical point of view, are highly important.

On Nov 15:th we had reached a position 20 nautical miles north of the Equator. In a depth of 4 400 metres a 10 metre corer was sent down and brought up a 9 metre core of whitish globigerina ooze, distinctly stratified in its lower parts.

In the ships engines, which had so far been in good working condition, a break-down occurred on Sunday Nov 16:th, which delayed us for half a day, since the speed under sail

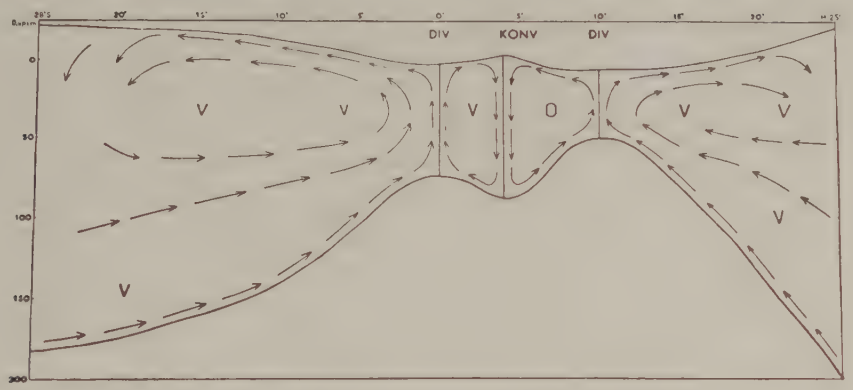


Fig. 69. Vertical circulation near the Equator.

as quite slow with the very faint breeze lowing. Owing to the roughness of the sea-ottom we were not able to take a new core ntil in the afternoon of Nov 17:th when a 3.5 metre core was raised from a depth of 150 metres. This time the detaching of the orer from the bottom proved much more ifficult than earlier, obviously due to our aving reached a different and tougher kind f sediment. The core was brown on top and urther down more whitish, but with variations nto brownish grey and dark grey with inter-paced »flames» of light-brown shade. The ower sections displayed a more variable oloration with two distinct boundaries, one n 12.8 metres, the other in 13.5 metres below he sediment surface. The interpretation made n board was, that below a layer of radiolarian oze there was globigerina ooze with signs ither of delving organisms or/and of slumping.

On Nov 19:th a more serious breakdown ccurred in the engine, in consequence of which considerable quantity of our precious lub-icating oil was lost. Until this break had een repaired we were drifting in a dead calm owards the east at a speed of about 1 knot, hich inevitably added to the delay in our inerary. Added to this, neither hydrographic or coring work was feasible, involving a total oss in the time available for work of nearly days. Since we could not risk putting off further our arrival at Honolulu, for which we were heading, the only work carried out during the next week, Nov 21:st to 28:th, was a few oceanographic series and a seismic experiment which gave a subsurface echo from a depth of 190 metres, an unusually high value for the Pacific Ocean. The following short table gives the sediment thickness found between Papeete and Honolulu.

Lat. 13° 25′ S. long 149° 30′ W depth 4 630 m, subsurface echo 135 m.
Lat. 04° 04′ S. long 152° 53′ W depth 5 170 m, subsurface echo 50 m.
Lat. 00° 20′ S. long 151° 31′ W depth 4 470 m, subsurface echo 60 m.
Lat. 08° 17′ N. long 148° 41′ W depth 4 940 m, subsurface echo 190 m.

One half of the seimsic attempts carried out failed to give any subsurface echoes.

It seems, at this stage of the narrative, desirable to give some details from the hydrographic work carried out in the equatorial region of the Pacific Ocean by our hydrographers, JERLOV and KOCZY, assisted by BRUNEAU, our chemist (BRUNEAU, JERLOV, KOCZY 1953). Our plan of action in the Pacific Ocean included the crossing of the system of equatorial currents by 4 sections with serial observations. The first section, started in the beginning of September 1947, was laid obliquely,

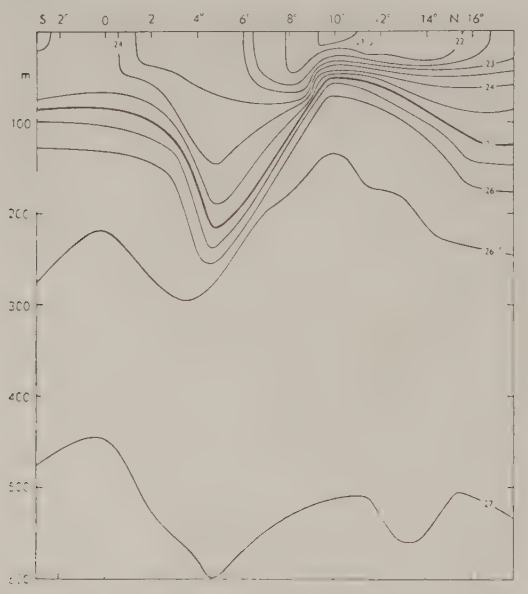


Fig. 70. Vertical section through Equatorial currents.

nearly parallel to the N American coast, from the Galapagos Islands up to latitude 18°N. The course from there was changed for the WSW towards the Marquesas Islands and ran across the equator to latitude 3°S, where the ship arrived on Oct 9:th. The third section, Tahiti - Hawaii, was run in November in a nearly meridional direction. The spacing of the stations was about 2° with a time interval of about 24 hours. The serial observations were usually limited to the uppermost 1 000 metres, but at some selected stations and, especially near the Equator, they were extended to the proximity of the bottom. Between the stations surface observations of temperature and salinity were made once an hour for about every 7:th mile. Bathy-thermograms from the surface down to 130 m were taken every 30:th mile. One of the density sections is here reproduced in figure 70 from JERLOV's paper (JERLOV 1953). The rise and close packing of the density curves near 10°N reveals the divergence at the northern boundary of the Countercurrent, wheras the minimum at 5°N marks the convergence at its southern boundary. In the third section, between Tahiti and Honolulu, the same characteristic features were found but with two maxima at the northern divergence, one at 9°, 5 N, the other one at 13°, 5 N.

Attempts to calculate the horizontal velocities of the currents on the basis of the oceanographic observations gave values approaching or even exceeding 100 cms/sec of the west-going current under the Equator, whereas the east-going Countercurrent between 5° and 10° N in the Hawaiian section barely exceeds 6 cm/sec. near the surface. The total water transport by the Countercurrent JERLOV found to be 36 million tons per second in the second section, 25 million tons in the middle section and 43 million tons in the westermost section made after Honolulu.

The arrival of the expedition in Honolulu had there been eagerly expected and wireless messages were received on board asking for the number and names of the members of the science staff, demanding public lectures and conferences and offering hospitality to us all. As we approached the harbour of Honolulu we had visitors from the air, planes passing close to the ship from which aerial photographs were taken. These were followed by racers, also with photographers on board. In the evening of Nov 29:th the »Albatross» made a stately entry into the harbour of Honolulu with a glorious sunset behind her, in which, for the fourth time during the Pacific cruise, we saw the much discussed »green ray» from the sun, just as it dipped beneath the horizon.

An orchestra on the quay played to us and a quartet of charming singers and dancers gave us songs of welcome. As soon as the ship had been moored to the quay, the reception committee came on board, decorated us with leis and invited us to a series of festivities which had been planned for the following week.

Scandinavians and their descendants play a prominent part in Honolulu, where names like Mattson, Olson, Larsen a. o. are well known and highly respected. Members of the Scan-

avian Union, called »Swe-Nor-Den» were our osts and gave us a splendid time during the wo weeks, into which our stay in Honolulu ad to be extended for the overhaul of the gines and for repairs to our scientific gear. ll in all the stay in Honolulu was the high ght of our cruise through the Pacific Ocean.

Honolulu and the Hawaiian Islands

From the viewpoint of a geophysicist, and specially of an oceanographer, the Hawaiian slands occupy a unique position in the Pacific Ocean. Built up from great depths through normous submarine eruptions on the ocean oor, the islands are mainly composed from extinct volcanoes. However, the very largest mong them, the giant volcanoes Mauna Loa nd Mauna Kea on the island of Hawaii, are till intermittently active. No wonder that he leading volcanologist of our time, Professor A. T. JAGGAR, had been attracted to this giant volcanological laboratory, which he studied for several decades. He has since then passed away, a great loss to Science and to his many friends all over the world. At the time of our visit he was fortunately still alive and gave us the benefit of many stimulating and helpful discussions. He was most interested in the results obtained from the »Albatross», which testified to the presence of extensive lava-beds in great depths. JAGGAR wished us to stay with the »Albatross» in Honolulu for a couple of years. He promised to keep us fully occupied with the investigations he suggested. For lack of time we had, unfortunately, to decline this most tempting invitation!

Also with other distinguished colleagues in the geophysical sciences in Honolulu we had many stimulating discussions. At a round-table conference, arranged for us at the University of Hawaii, the different members of our staff had opportunities for laying their special investigations before the men of science present and to answer their questions and profit from their advice.

Fig. 71. Map of Hawaii Islands.

On the invitation from the Chamber of Commerce in Honolulu I had to deliver a public lecture on the general purpose of our cruise and on the results so far gained. After dwelling at length on the magnificent opportunities for deep-sea research offered by the regions round the Hawaiian Archipelago I concluded my exposition by saying:

»We Swedes on board the »Albatross» have come half way round the earth in order to study problems of the ocean bed which are at your very doorsteps. Is it not time that you here take up similar studies and carry out deep sea research for which you have such unique possibilities?»

I have recently to my great satisfaction been informed, that such initiative is at present being taken and that Congress will be asked to vote a sum of 1 000 000 dollars towards the costs of establishing at the University of Hawaii

Fig. 72. Swedish-Hawaiian collaboration.

a permanent geophysical institute with research facilities for visiting scientists.

Our generous hosts in Honolulu arranged both entertaining and instructive excursions for us during the fortnight we had to stay in Honolulu in order to have the »Albatross» docked. Some of us profited from our stay in Honolulu for making a trip by air to the Island of Hawaii, visiting the Natural Park there and motoring up to the crater of Halimaumau, which had been in eruption shortly before our arrival. The impressive remnants from earlier eruptions in the shape of lava streams of different ages, carefully labeled with the »vintage years» for the information of tourists, were highly spectacular.

Volcanic eruptions are not the only catastrophes to which the Hawaiian Islands are exposed. Another menace comes from the »tidal waves», what the Japanese call tsunamis, which are set up by tectonic or volcanic disturbances of the ocean bed. The waves travel over oceanic depths at velocities of several hundred metres per second. Such a tsunami had been occasioned by a sudden subsidence of the bottom near the Aleutean Islands on April I:st of 1946, i. e. some 21 months before our arrival. The waves had travelled in 10 hours to the shores of the Hawaiian Islands and there given rise to devastating breakers with extensive damage to property and loss of human lives. More than 120 schoolchildren, who had been on an excursion on the shore near the city of Hilo, were deluded into following the retreating waters off the beach and were drowned by the sudden rise of the returning water.

In order to avert similar disasters in the future a system of tsunami-warnings has been established, based on seismic observations with the purpose of preparing the islanders against impending inundations.

We had a serious set-back during our stay in Honolulu through three of the crew deserting the ship. Although a search was made for them with the assistance of the authorities, they could not be found and we had to leave the harbour of Honolulu on December 14:th three hands short. We were informed afterwards that the three absentees had turned up a few days after our departure and demanded to be sent to Tahiti, which evidently had struck their fancy. The police, however, did not agree to that suggestion, so the men were instead sent to the mainland and from there back to Sweden, where presumably their families had some comments to make on their flight from the »Albatross».

A more serious problem which came up in Honolulu was a warning by cable from the owners of the ship, that our expenditure had considerably exceeded the estimates, so that we were already 200 000 kronor short and would ,therefore, have to curtail severely the program for our continued cruise. However, after an exchange of telegrams, our generous donors intervened and the missing capital

was subscribed, thus enabling us to continue our cruise round the world.

As a token of the goodwill of our friends in Honolulu we were amply provided with material for Christmas cheer, including two Christmas trees which had been imported from Oregon. Especially to our young apprentices this gift was a real boon. It would have been very hard on them to have to celebrate Christmas on board without any »julgran».

Honolulu to Ternate

On Dec. 14:th 1947 we abandoned all hope of retrieving our three deserters. Since the second engineer had resigned for ill - health, we were actually four hands short, when we started on our cruise in the western Pacific. A crowd of our Honolulu friends had come to see us off. Some of them on board a large motorboat even escorted us for the first few miles, signalling to us to return soon to Honolulu.

The weather was fine, the moderate breeze blowing, however, soon freshened and was accompanied by a swell from astern. Thanks to the cleaning which the bottom of the ship had undergone in Honolulu, we made good speed, averaging 8 to 9 knots. Our course was set to the SW as we wanted to traverse the equator for a fourth oceanographic section across the equatorial Countercurrent.

On Dec. 15:th the wind from the NE had freshened so much that we desisted from raising a core. The swell had increased also on the following day, but a coring operation was attempted with a 5 metre corer which brought up very little sediment, probably owing to the corer having hit on hard manganese concretions, a few of which were found in the lower part of the corer. The same obstacle was encountered on Dec. 17:th. A further complication was that the internal wire rope happened to snap. We were in fact lucky not to lose the corer altogether, as

Fig. 73. The effects from a squall.

might easily have happened. The echograph had been drawing a fairly smooth curve over considerable depths, mostly about 5 500 metres, with occasional rather abrupt jumps to smaller depths. Thus near 13° 48′ N 165° 40′ W there occured over a distance of only 14 nautical miles a rise in the bottom profile from 5 178 m to 2 763 m, but already 10 nautical miles further a depth of 5 300 m was recorded. Fifty miles further to the SW a still more pronounced rise and fall of the bottom, this time by nearly 3 000 metres, was recorded. It seems highly probable that in both cases our course had cut across one of those remarkable submarine mounts called »guyots» which, according to recent publications by R. Dietz (Dietz, 1954) have been discovered in great numbers in the NW Pacific Ocean. The same experience was repeated still further to the SW, where, in lat. 10° 19′ N, long. 167° 53′ W, a minimum depth of 1 809 metres was recorded. Otherwise the depth over the greatest part of our course remained at more than 5 000 metres.

Over a short distance in 6° 43′ N, 171° 36′ W the depth even exceeded 6 300 metres. Just north of the equator in 0° 13′ N 176° 30′ W a minimum depth of only 729 metres was recorded whereas 10 nautical miles further south the depth increased to 5 356 m. Presumably we had also here crossed a guyot, a conclusion which we, for lack of time, could not confirm. After crossing the latitude 2° S the »Albatross» followed a westerly course which brought us over depths at first exceeding 5 000 metres, but, after traversing the 174:th meridian east, the depth decreased to somewhat more than 4 000 metres and from the 162:d degree east the bottom profile rose to between 3 000 and 2 000 metres. We had left the great depth basin of the western Pacific Ocean and approached shallower regions.

Amongst the cores raised during this part of the cruise the following were of special interest. On December 22:d, with an 11 metres corer, a core of red clay, rich in radiolarians, was raised from a depth of 5 600 metres, length of the core being 10.6 metres. Subsequent studies of the radiolarians in this core proved them to be very ancient, evidently a case of old sediment laid bare through erosion by bottom currents. On the following day another red clay core, rich in radiolarians was raised from a depth of 5 500 metres, its length being 10.2 metres. Again on the following day a core of the same length was raised from a slightly greater depth. Also here the upper parts of the core were subsequently found to hold a mixture of Tertiary and Recent radiolaria. Later measurements in the laboratory proved the radium content to rise to two distinct maxima, one in 15 cms and the other in 35 cms below the sediment surface, whereas near the latter maximum was found a small manganese nodule with a very high radium content.

This happened to be Christmas Eve which, amongst Scandinavians, is held as *the* great Christmas festival. It was duly celebrated on the »Albatross», where all on board gathered for a common feast with excellent fare, Christmas trees with traditional decorations, a gift from friends in Honolulu, presents to all members of the cruise, accompanied by poems of a hilarious tenure. Speeches were made, songs were sung and especially the youngsters on board enjoyed themselves greatly.

Christmas Day no coring or other science work was carried out. On December 27:th another red clay core, 10 metres long, was raised from a depth of 5 400 metres, our last one of homogeneous red clay obtained from the western Pacific Ocean. Owing to our passing the datum line December 28:th dropped out of our calendar. On December 30:th the wide-bore corer made in Honolulu was tried for the first time in a depth of 4 800 metres with complete success. It brought up a core 5.1 metres long, necessarily much shorter than the cores taken with the narrower corers. Its upper part consisted from red clay, poor in lime, whereas from 190 cms depth below the sediment surface and downwards the red clay was replaced by calcareous ooze with numerous forams.

From the core thus obtained there have subsequently been extracted a large number of magnetic spherules, fragments from meteors heated to incandescence during their flight through the atmosphere as »shooting stars». The variations with depth in their numbers affords an insight into the varying frequency of meteors during the span of time required for the accumulation of 5 metres thickness of sediment, i. e. a few million years.

The next core, taken on New Years Eve, was raised from a much smaller depth, just over 4 000 metres. It had a length of 16 metres and consisted from calcareous ooze, containing large numbers of foram shells. We had now definitely come over from the deep ocean basin carpeted with red clay to a region of much less depth, where the calcareous ooze dominates. New Years Eve was duly celebrated

y an excellent dinner on deck, with songs peeches and a few TNT detonations at a afe distance.

On January 2:d another thick core was aised from a depth of nearly 4 000 metres. 'alcareous ooze dominated in this core, alternating with red clay of relatively high lime ontent. Its total length was a little more han 5 metres. Also from this core magnetic pherules of cosmic origin were subsequently xtracted. In immediate vicinity of this coring tation a narrower but much longer core of 5 metres length was raised from the same lepth. It consisted from calcareous ooze ich in forams especially in the uppermost 3 netres of the core.

On January 3:rd a fresh attempt was made vith the geothermometer over a depth of 4.450 netre, lat. S 00° 09′ long. E 165° 26′. The steel ube this time had a length of 12 metres, so hat the lower end containing the thermometer vas immersed practically to this depth into he sediment. It gave a temperature differ-nce above the temperature of the bottom water of 0°,40 C, corresponding to a geothermal gradient of 1° centigrade for 25 metres, i. e. slightly less than the earlier value found under he Equator further east.

The coring work was interrupted for 3 days which were largely devoted to a visit to the Kapingamarangi atoll, where our oceanographers had important measurements to carry out.

The Kapingamarangi Atoll

We had been strongly adviced by our friends at the Bishop Museum in Honolulu to visit a small atoll called Kapingamarangi, situated on Latitude 1° 04′ N, longitude 154° 48′ E. It is a very remote cluster of coral islands, rarely visited by ships and, therefore, very little influenced by the external world. However, a more weighty argument for complying with this suggestion was the ardent desire of our oceanographers to measure in the undisturbed water

Fig. 74. Map of Kapingamarangi atoll.

within the atoll the intensity of the ultraviolet components of submarine daylight penetrating into the clear water.

It would have been impossible for the »Albatross» to navigate through the narrow channel leading between coral reefs and islets into the lagoon. The ship was, therefore, ordered to stand by at a safe distance outside the reef. We took instead one of the motorlaunches under the command of Captain KRAFFT himself, in order to reach the shores of the small kingdom, ruled over by King DAVID and his buxom Queen VIORA. To us visitors the experience was unique, afforded by clusters of stately palms rising like green bouquets over the dazzlingly white coral sand. We had a hearty welcome on shore and we distributed small gifts, of which a load of illustrated American papers and magazines were most appreciated. The friendly subjects of the benevolent King DAVID crowded round the audience hall, where the King received us in state and later, like the King himself, they offered us generous hospitality. We were allowed to watch them at their various occupations, from household work, weaving and hairdressing to canoe-building, in which the islanders are highly proficient.

His Majesty is strongly religious and frowns on alcoholic drinks and even on smoking. In fact the same word is used for »Christian» and for »non-smoker»!

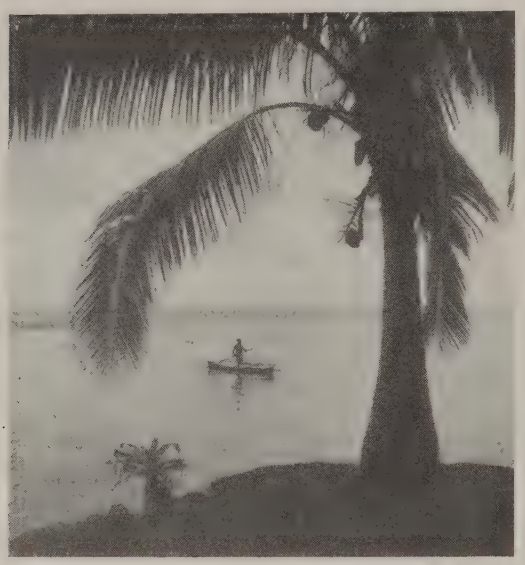


Fig. 75. View from Kapingamarangi.

In the meanwhile JERLOV carried out successful measurements of the ultraviolet submarine daylight in the lagoon. He found that, contrary to our expectation, the surface layers in the tropical water have a surprisingly high transparency to ultraviolet daylight, much more so than the rather turbid waters round the coasts of Sweden and inside our fjords, probably owing to the sharp cut-off which is there caused by products from organic »detritus» dissolved in coastal waters. Whereas near Bornö Station the intensity of the ultraviolet light of wavelength 3100 ÅNGSTRÖM is reduced to 10 % by a waterlayer 1 meter thick, the crystal clear waters in the Kapingamarangi lagoon allow ultraviolet light of the same wavelength to retain 75 % of the surface intensity after its passage through 1 metre thickness of water. A still higher transparency to UV-light was later on found in the open ocean, leaving 86 % of surface intensity in a depth of 1 metre.

This altogether unexpected result considerably modifies our preconceived ideas on the biological effects on surface organisms from the short wavelengths of daylight.

After two days and a night, which many of us passed on shore as guests of King DAVID we on board the »Albatross» left this rarely visited haven of peace and piety and restarted on our cruise towards the west.

Kapingamarangi to Ternate

During the following three days the »Albatross» followed a westerly course, keeping close to the Equator. Three cores, taken from depths varying between 2 200 and 3 000 metres, had lengths of about 9 metres. They consisted from a clay fairly rich in forams with occasional layers of foram sand. Stearing WNW with increasing northerly latitude we found the depths gradually increasing. The cores raised still consisted of clay with numerous forams. On latitude N 02° 16; long. E. 148° 45′ from a depth of 6 080 metres a core 1.5 m long was raised. It contained red clay with an admixture of foram shells and with occasional strata of foram sand. In the uppermost levels darker layers containing volcanic glass occurred.

The core raised on Jan 11:th from a lesser depth, 4 500 metres, had a length of nearly 1 metres and consisted of red clay poor in lime. It obtained the number 100 in our protocols and the event was duly celebrated at our dinner with toasts to KULLENBERG and to JONASSON. The cores raised during the following week 14—21 of January, from depths of 3 700 to 4 500 metres consisted largely from clay with a low content of lime, but displaying a tint in greyish green, due to a considerable admixture of organic substance.

On January 22:d the rapidly increasing depth announced our approach towards the great Philippine trench, where one of the greatest depths of the whole ocean is located. Time did not permit us to deviate so much from to the north from our course as to reach the celebrated »Emden Deep», since investigated by American and Danish expeditions. Our deepest core from the whole expedition, 7 785 metres, was taken in latitude N 04° 43′, longitude E 128° 06′. The

ppermost few oms consisted from fairly coarse ınd, the rest being dark brown clay with arked stratification. In the lower parts (total ngth of the core = 4 metres) there was an- ·her layer of more or less fine sand. A minera- ·gical study of the core, carried out later by .. Fredriksson, gave the following results: ·ı the uppermost 4 cm of the core there is sand nd also between the depths 285—400 cms umerous layers of sand occur, built up largely ·om grains of andesite and basalt, whereas ·uartz is practically absent (a description will e published by Fredriksson in these Reports). ıfter having reached a still greater depth we ıade an attempt on the following day, Jan. 3:d, to obtain a core from the depth of 8 400 ıetre by means of a prolonged cable. Un- ·ortunately the cable snapped, so that both he corer and its precious content was lost. Ve, therefore, desisted from further coring vork and steered south for Ternate.

The seismic experiments carried out in the vestern Pacific gave relatively meager results. At a few stations on our way from Honolulu owards the Equator a peculiar kind of sub- ·ottom reflections were recorded, which indi- ·ated a watery, homogeneous sediment layer, ·overing either rock or a much tougher kind of ·ediment. This interpretation is strengthened ·y the interesting fact, that the echograph at hese stations between latitudes N 17° 46′ and N 11° 30′, the longitude being slightly more han W 127°, failed to record any bottom reflections at all. The thickness of this watery ayer varied at the different stations between 20 and 140 metres with an average value of 85 metres. The few ordinary sub-bottom re- flections found further SW varied between 100 ınd 200 metres.

Attempts to obtain sub-bottom reflections n the Mindanao Trench, where it would have been most interesting to find a value for the ·ediment thickness, failed, owing to disturb- ınces from the multiple echoes reflected from he steep walls of the trench.

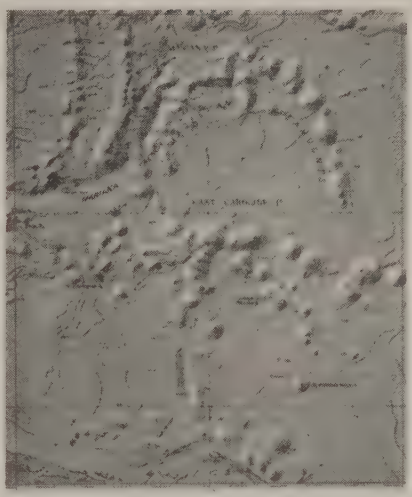


Fig. 76. The »guyots» in W. Pacific.

The existence of a special »deep-scattering layer» in depths of between 50 metres and several hundreds of metres was repeatedly observed. It has been interpreted as due to compact swarms of pelagic organisms or, in certain cases, swarms of fish. Quite frequently such diffuse echoes in intermediate water strata were recorded, especially after we had gone over to use a wire-recorder instead of the oscillograph. A close examination of 77 records proved, that in not less than 55 of them so-called »D-signals» from scattering layers were present.

Animal noises were very often recorded by the hydrophones used for the seismic explosion echoes. The pulses received per second varied between 4 and 31, with an average frequency of 14/sec. The prevalent views of the muteness of marine organisms are obviously no longer tenable. This especially applies to fishes, who seem to be quite locacious, when they are assembled in shoals.

The expedition reached Ternate on January 26:th 1948, having crossed the Pacific Ocean from Balboa via the Galapagos Islands, Nukuhiva, Tahiti, Oahu and Kapingamarangi in almost exactly 5 months.

Ternate and the Sunda Archipelago

The small volcanic island of Ternate, one of the famous Moluccan group, the »Spice Islands», which were objects of a hot competition between Portugal, Spain and Holland during the 16:th and 17:th centuries, has been visited in modern times by several scientific expeditions. We on board the »Albatross» passed three restful and very pleasant days at Ternate, where we were received with great courtesy and hospitality, both by its native ruler and by the Dutch »resident». The small town had been badly ruined through bombardment during the second world war, when it was occupied by Japanese forces. Only the palace of the Maharajah had remained undamaged. We were graciously invited by her Highness the Maharanee, her husband being in bed with a touch of malaria. We were even allowed to see the hereditary treasure chest with its riches from bygone centuries, helmets and daggers of solid gold and silver, a sight which R. L. STEVENSON would have enjoyed. At the approach of the

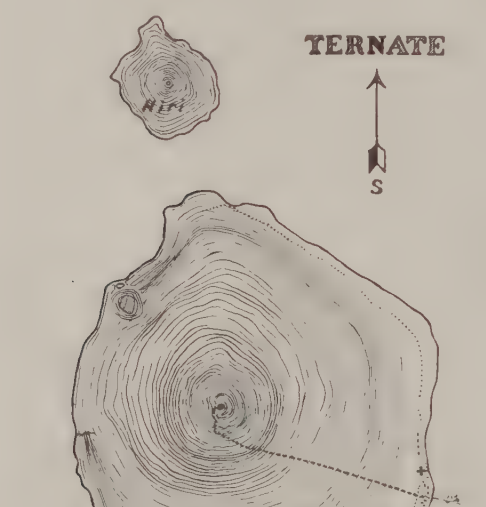


Fig. 77. Map of Ternate.

Fig. 78. Fishing at Ternate.

Japanese the faithful servants of the Maharajah who was fighting as an officer in the allied forces, had carried the heavy treasure into the jungle and hid it there from the rapacity of the invaders.

Our sejour in the harbour of Ternate was not without incidents. A fairly strong earthquake occurred, which made the »Albatross» jump at her moorings, as if she had run aground. This earthquake happened to coincide with our intrepid doctor's ascent to the top of the high (1 500 m.) volcanic peak. His native carriers had warned him, that the volcano is sacred, and that the gods might object to a sacrilegious descent into the crater. At the quake they dropped their burdens and fled shrieking with terror. However, Dr. ERIKSSON and his companion calmly resumed their descent from the summit and returned unpunished to the ship.

Well provisioned we left Ternate on January 29:th resuming our southward course toward the island of Java.

On February 1:st, a Sunday, the echograph drew a remarkable, perfectly flat curve, with a number of sub-bottom equidistant curves no less than 10 in number! Whether this was due to a pronounced stratification of the deposi or to some instrumental error seems doubtful. It would have been most tempting to take a core at this locality in order to make out whether there was a distinct stratification

isible. Unfortunately it was too late at night or a safe handling of the heavy core-sampler, part from it being a Sunday. Nor did our inerary allow us to lose 8 hours or more by emaining stationary at the same position until dawned. So with a sigh of regret I had to esist from the opportunity offered.

The echograph curves displayed a variegated ottom profile in the Sunda Archipelago, espeially when approaching one of the submarine arriers between the different basins. On the ther hand, the profile was quite flat near heir centres. Thus on February 4:th in the 'lores Sea the depth remained practically contant at somewhat more than 5 000 metres, ffering ideal conditions for coring. Unforunately our corer was just then under repair, wing to its having the previous day hit on a ard bottom. This caused an »implosion» of ome of the brass lining - tubes which made hem most difficult to extricate, so that an - ther excellent opportunity was missed. The ery strong adverse currents repeatedly encountered set us so far back in our schedule hat we did not arrive at the designated coring stations until late at night, when it was considered unsafe to start coring operations.

Our first core in the Sunda Archipelago was raised from a depth of nearly 3 000 metres in

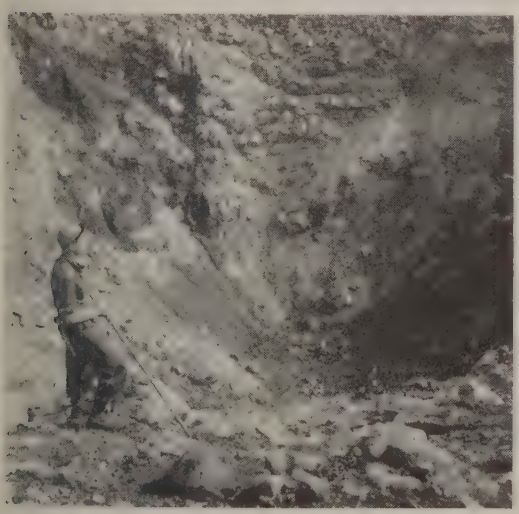


Fig. 79. From the crater on Ternate.

Fig. 80. Measuring UV daylight.

the northern part of the Banda Sea. It had a length of nearly 9 metres and was dark green in colour, probably due to a strong admixture of organic matter. It contained numerous foram shells and also some pumice fragments. On February 6:th a 12-metre core was raised from a depth of 1 300 metres in the Banda Sea. Its upper parts down to $2\frac{1}{2}$ metres below the sediment surface consisted from a homogeneous clay of a grey-greenish colour. Two almost black layers, rich in organic remains, followed and in a depth of a little over 4 metres there was a dark layer of volcanic ash. Also below 10 metres there was more volcanic material but of a lighter shade. The same applies to an 11.5 metre core raised on the following day from a depth of 970 metres. A pronounced stratification was apparent, the uppermost 4 cm thick layer, which was very brown in colour, differed from the lower parts which were dark grey in colour with a greenish tinge.

In most cores raised between Ternate and Surabaya the greenish colour dominated, in some cores accompanied by a strong smell of sulphuretted hydrogen. Foram sand and volcanic ash were frequent additions.

The seismic experiments gave no definite sub-bottom echoes, owing to the number of spurious reflections from the irregularities of the bottom profile. Nor were our attempts to use the geothermometer successful, as the clockwork regularly stopped in the cold bottom water. On the whole, the passage through the Sunda Archipelago was the least successful part of our cruise. Moreover, samples from the sediment cores, which offered many points of interest, were afterwards confided to a Dutch specialist on volcanic ash horizons in Indonesian waters, but were largely lost, owing to the illness of the investigator.

Surabaya and Java

On Februar, 8:th the »Albatross» reached the harbour of Surabaya. The approach was not without risks due to the number of wrecks from ships sunk by the Dutch when the Japanese invasion was expected. We had a cordial reception at the Dutch Naval Station and the privilege of an excellent berth at the Naval Quay, and were hospitably entertained by the chief of the squadron, Commander VAN VANING and his officers. Also the Swedish Consul and Mrs WIESLANDER were most hospitable to us.

Thanks to generous assistance from the naval authorities, we were able to have diverse repairs to our equipment carried out in their workshops in Surabaya in time, so that we could start with the necessary reserves in coring tubes. But on the other hand, oil for our diesel engines was extremely scarce, both in Surabaya and in the whole of Indonesia, owing to the skilful bombing of the oilwells by US planes during the Japanese occupation. Instead of sailing straight across the Indian Ocean south of the Equator, as had originally been planned we, therefore, had to plan for a detour to Colombo on Ceylon in order to obtain bunkers.

We were invited to sight-seeing tours up into the hills, from where we had a glorious view over Java and over the surrounding sea. The temperate climate up there we felt most refreshing after the rather oppressive, moist heat of Surabaya, where the pressure from the tropical climate made itself felt by us northeners.

The Indian Ocean

From Java to Ceylon

Acting on the advice of our Dutch friends in Surabaya the expedition paid a short visit to the famous island of Bali, the much renowned »Isle of Beauty». There we had the good fortune to be received by one of the foremost artists of Indonesia, the famous painter ADRIAN JAN LE MAYEUR DE MÈRPRES and his lovely wife, formerly a celebrated dancer. We were their guests in their home on the beach, where we had an exquisite lunch and were allowed to admire the paintings which filled the walls of their home. Together with my son I spent the whole day with these delightful hosts, whereas the other members of the expedition made an excursion up into the hills and enjoyed the wonderful views and the picturesque folk-life especially near the holy sources of Tampaksiring.

Our artist host exhorted us to stay for a couple of days so that we might see the famous ritual dances which he offered to arrange.

Unfortunately I declined this most tempting invitation, since we were already behind our schedule and had the Indian Ocean waiting for us. As events turned out, we might quite as well have stayed in Bali for nearly one week. Driven by a sense of duty we set out from the Isle of Beauty only to run into a severe gale, the worst we had on the whole

cruise and which prevented us from doing any scientific work whatever.

The eastermost part of the Indian Ocean is in bad repute amongst sailors since it is often frequented by tropical storms, occasionally such of great severity. They use to take a southerly course and, when they rage, make the approach to the barren and rocky coast of western Australia quite dangerous.

On February 18:th the wind was blowing with Beaufort 8 to 10, i. e. from 15 to 20 metres per second. On the following day it developed into a full gale. The crests were torn off the waves and blown into salt spray, making the range of vision on deck very limited. The »Albatross» was behaving beautifully in the heavy sea, but was rolling by nearly 36° to either side, the height of the waves gradually increased to about 8 metres, over 25 feet. Eating became an equilibristic problem at mealtime, requiring an almost acrobatic agility. No serious damage was done, in spite of the heavy turmoil below deck and in the laboratories, save for the breaking of a large glass container with formaldehyde, which temporarily forced some of us to use gas masks.

Having been warned by wireless weather reports that our course was converging with that of the centre of the cyclone, we found it advisable to change our southerly course through 180°, a manœuvre which Captain. KRAFFT carried out in a masterful manner without any mishap. On the 21:st of the month we were outside the stormfield, but the sea was still running high and we just managed to — regain the position south of Bali which we had left four days earlier, so that we could again steer towards the west.

On February 23:rd the wind had abated and the swell was much reduced, so that the corer was put out over a depth of about 3 600 metres. However, luck was against us. The depth increased so rapidly during the operation, that the corer tumbled over and its lower part was lost.

Fig. 81. Gale in the Indian Ocean.

On the following day, leap-day, we had reached the great Sunda Trench, where another shot was made over a depth of about 6 800 metres. No sediment was obtained but instead stones in an almost empty coring tube. A surprising fact to hit on hard bottom in such a great depth! On the following day, February 25:th, we were criss-crossing over the Sunda Trench our echograph twice recording a maximum depth of 6 864 metres in the position S 10° 08′, E 108° 55′. This is several hundred metres less than the official maximum depth, found by a Dutch mine-sweeper by mechanical sounding, which was well over 7 300 metres. From this great depth a 7½ metre long core was safely brought up. It consisted from greyish clay, poor in lime and getting much finer in structure near the lower end with an admixture of organic matter. From this great depth large-volume water samples for radium measurements were raised and, in addition, an oceanographic series was made. On the following day, about 160 natuical miles to the WSW, an attempt to raise a core from a depth of about 5 200 metres failed, as

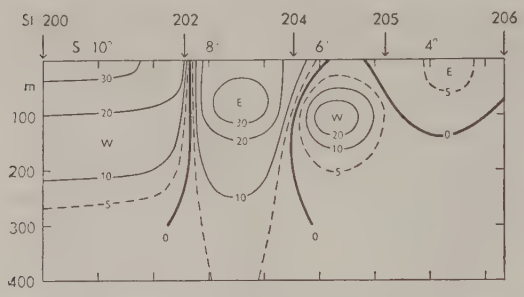


Fig. 82. Horizontal velocities (cm/sec) in a vertical section between 11° and 2° S m the Indian Ocean (near 88° E) (Vol III, fig. 12 p. 122 JERLOV).

the corer again hit on hard bottom. On the following day, however, we had better luck and a core 11½ metres long was raised from a depth of 5 600 metres. The content was again clay with a few radiolarians and forams in the upper part. In a depth of nearly 3 metres there were 13 cms of fine volcanic sand, whereas below 6.7 metres there were layers of more or less coarse foram-sand mixed with organic matter.

On February 26:th Christmas Island was sighted about 30 nautical miles to starboard. The phosphate mine, discovered on this island by the chemists of the Challenger Office, proved extremely valuable, and Sir JOHN MURRAY and his family derived great riches from their exploitation. Part of the income from this source Sir JOHN set aside with instructions in his will, that the accumulated capital should serve to finance an oceanographich cruise to the northwestern Indian Ocean, which had not been visited by the Challenger. This project was realized 20 years after his death by the »John Murray»-expedition on board the Indian research vessel the »Mabahiss,» which gave important results. At the time when we passed Christmas Island negociations were afoot for its cessation by the Phosphate Company, dominated by the heirs of Sir John Murray, to the Australian Commonwealth, negociations which have since been carried through.

On February 28:th a core raised from 5 170 metres, 11 metres long, consisted from silt with grains of sand and some volcanic glass. The core was strongly stratified. Down to 5½ metres it was grey to greenish with shades of brownish colour. Below 5½ metres there were repeated layers of calcareous ooze, alternating with brownish grey sediment. Stratification was especially pronounced in the lowest section between 10.8 and 11.4 m, where red clay was predominant.

Following our westerly course between the 11° and 11° 30′ S, the echograph drew a fairly even bottom curve, the depths varying between 5 700 m and 4 700 metres, with occasional seamounts rising up to 2 400 m or even 1 700 m. Approaching the 88° E the bottom profile got more varied, with a maximum depth of 6 086 m not far from a seamount of less than 2 000 m, possibly an extension of a bank, which had been sounded about 120 nautical miles further south, with depths of between 2 000 and 2 200 m.

On March 4:th the wide-bore corer was used, as the ordinary corer happened to be under repair. From a depth of 5 200 metres it brought up a core only just over 3 m long. It appeared that the corer had hit on a hard layer (a lava bed?) preventing it from penetrating further down. The sediment was light brown in colour in the upper parts, further down dark grey with a distinct stratification. There were several layers of sand, and the clay was fairly rich in radiolarians.

Having passed the 88:th eastern longitude we changed our course towards the north steering from latitude 11° S along the eastern longitude 88° 30′ for Colombo. Leaving the northward slope of our »bank», the depth rapidly increased to 4 800 m. Between 6° S and the continental slope of Ceylon the sea floor is slowly ascending between the sea mountain at 3° N and the slope to wards Ceylon The sea floor is extremely plane. A surprising rise in the bottom profile from 4 030 m to less than 100 metres occurred in N 5° 31′, E 80°

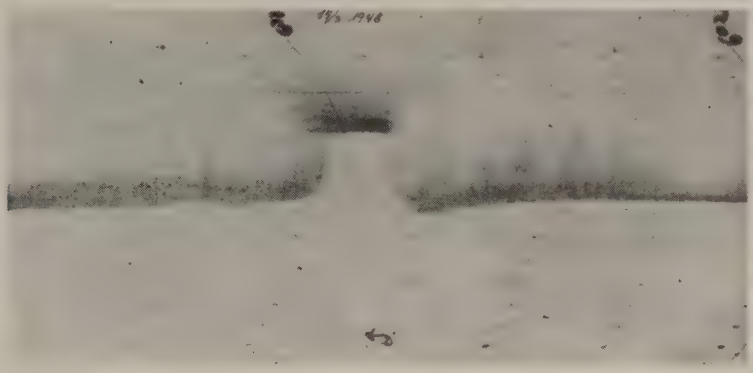


Fig. 83. Echogram from Indian Ocean.

7', the minimum depth, 58 metres, occurring t N 6° 01', E 79° 59', signalling our approach owards the shelf around Ceylon.

A curious profile was recorded by our echo-raph at about N 4° 26' E 82° 45' where we rossed four channels with steep brinks and n apparently flat bottom, see figure 7 taken rom Dr Koczy's paper on our echograms. R. Dietz (1953) has attempted to interpret hese channels as excavated by »turbidity cur-ents», assuming it to be a continuation of sub-narine canyons off the Ganges delta. Koczy 1954) has taken exception to this explanation, which has, moreover, lost in probability, since ttempts, to find a continuation of the same chan-nel further north made from a British expedition with HMS »Challenger» have failed. Koczy's own nterpretation is that the channel is a fracture, lue to a tension in the rocky substratum, earing superficial sediment layers apart.

The oceanographical series and the optical nvestigations carried out from the »Albatross» n the central Indian Ocean gave interesting ictures of the vertical distribution of particles nd also of the computed distribution of current velocities in a section between 11° and 2° S, ear the 88:th parallell eastern longitude. This is demonstrated by one figure, published n Jerlov's paper in Volume III. of these Reports. It is seen that the velocity of the Equa-torial Countercurrent in the surface is about 22 cms/sec or 0.4 knots, whereas its maximum strength is reached in a depth of 75 m, owing to a contrary wind prevailing in the surface. The main flow extends between 6° and 8.5° S, i. e. over a distance of only 300 kms. The South Equatorial Current, on the other hand has a velocity of 30 cms/sec or 0.6 knots. The particle-distribution is seen to have two very distinct maxima in a depth of about 50 metres, one in about 8° S the other in 2° S, both due to divergences in the current distribution, causing a high production of phyto-plankton.

An attempt to raise a core from an unusually plane stretch of bottom, encountered on our course from the Equator towards Colombo, failed, owing to the corer hitting again on hard bottom, presumably a lava bed.

Only one seismic experiment was under-taken on our way to Colombo. It gave a subsurface echo in about 100 metres.

A haul with our large ring-net made in a depth of 750 metres brought up some scarlet deep-sea shrimps, *Nostomus* spec. Another haul, made in half the same depth, gave a still meagerer catch.

On March 16:th the »Albatross» passed into the harbour of Colombo, where we were to take in bunker oil, carry out various repairs to our equipment and give the staff, the crew and the officers a well-deserved rest.

From Colombo to Port Victoria

In general geologists assume the Pacific Ocean to be of very great age, possibly one of the primary features of our globe. No early continental masses are assumed to have existed in the Pacific. On the other hand, the Indian Ocean is generally assumed to be much younger. The Australian geologist, R. W. FAIRBRIDGE, in a stimulating article on »The Juvenility of the Indian Ocean» (FAIRBRIDGE 1948) assumes this ocean to be the youngest of the three and to have been largely filled by a land block, the much discussed Gondwanaland, broken up in late Permain Time about 200 million years ago. In Trias Time, about 190 million years ago, a deep wedge of ocean spread from the north, almost separating East Africa from Madagaskar and India, whereas in Jurassic Time, about 150 million years ago, arms of the sea spread all around the northern borders of the Indian Ocean we know today. The relatively youngest part of the Indian Ocean lies in the northwest, where the Red Sea was formed in late Teriary Time, possibly not more than 15 million years ago.

The oldest part of the Indian Ocean, on the other hand, lies to the south-east in the Indo-Australian basin, where over a large expanse depths exceeding 5 000 metres are found.

Fig. 84. Depth chart of Indian Ocean.

A very remarkable formation is the Mid-Indian Ridge with its continuation to the NW, the Carlsberg Ridge, and to the SE, the Kerguelen-Gaussberg Ridge, running right up to the Antarctic Continent. This system of ridges separates the Indian Ocean into a larger and deeper easterly part and a more limited western part, divided into a number of smaller basins. See the barhymetric map of the Indian Ocean drawn up by FAIRBRIDGE, fig. 84, in which the course followed by the »Albatross» is marked by a black line.

Our course from Colombo, which we left on March 27:th, was laid to the SW, crossing the Equator to the SE of the Maldives, and from there to the west in order to reach the Seychelles. This course did not bring us over great depths, but it offered various other points of interest, especially the crossing of the Carlsberg Ridge.

On March 29:th we were informed by wireless that Mr WERNER, the great benefactor to our Expedition, had passed away, a source of great regret to us all, especially to myself who had got very fond of this most charming man. I tried to express our feelings of great regret and deep gratitude in a wireless message to the leading daily paper in Göteborg. We had lost a staunch supporter and a dear friend, and Göteborg had lost one of its most liberal and broadminded donors. On my return to Sweden I was informed, that Mr WERNER to the last had followed the news from our Expedition with great interest and repeatedly expressed his satisfaction with the results we had been able to report to him.

The cores taken during this part of the cruise were of moderate length, varying between 6 and 10 metres. The sediment was mostly calcareous ooze with an admixture of radiolarians, spongie-needles and, in some cases, of volcanic glass. Most of the cores

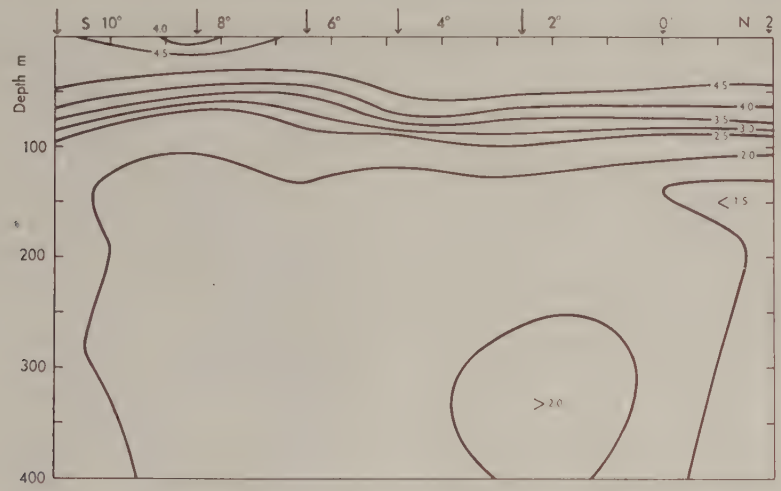


Fig. 85. Oxygen in a section between 11° S and 2° N (near 88° E) (Vol III, fig. 8, p. 119)

were strongly stratified and in some of them layers of red clay alternated with calcareous ooze. In one core, taken from 4 400 metres in S 01° 20′ E 64° 00′, to the west of the Carlsberg Ridge, there were signs of a reshuffling of the sediment *in situ*, presumably due to tectonic disturbances accompanied by slumping. The core was 11.5 metres long and in a depth 755 cm below the sediment surface, a layer almost 1 metre thick of non-calcareous red clay occurred. In several cores there were layers of coarse foram sand. Also in the following core, taken 100 nautical miles further west in a depth of 4 750 m there was, between 865 and 1 065 cms below the surface, a layer of red clay. It appears that the chemistry and/or the movement of the bottom - water has been more favourable for the dissolving of the lime from the sediment several hundred thousand years back in time than at present.

Our oceanographers seized the opportunity of our crossing the Equator for a deep series of water samples. Below a depth of 100 metres there was a sharp decline in oxygen content which fell to a minimum value of 0.50 ml/L of oxygen in a depth of 200 metres, as compared to 4.23 ml/L in 3 235 metres depth. From there down to the bottom, in 3 279 metres, the oxygen content fell to less than 1ml/L.

The uneven character of the bottom profile made coring hazardous. The cores taken on the first days of April were largely filled with calcareous ooze, alternating with foram sand. The echograph drew an interesting curve, occasionally with multiple profiles, resembling those obtained in the Banda Sea. On April 7:th attempts to raise a core from the depth of 4 640 metres failed, apparently due to a hard bottom covered with only a thin layer of sediment, presumably an extensive lava bed.

The Seychelles

We had been encouraged by an English admiral to touch at Port Victoria on Mahé, the largest island of the Seychelles, which he described as the »Paradise of the Indian Ocean». Since a visit there with a short rest for the crew and the staff fell well into our schedule, we followed his advice. The »Albatross» anchored in the harbour of Port Victoria on April 10:th, where we were received with great courtesey by the authorities, especially the governor Dr Selwyn Clarke, the only MD who has been made governor of a British Crown Colony.

The Seychelles are interesting from a geological viewpoint, in being formed from a kind of

Fig. 86. Map of Mahé.

granite, syenite, and not from basaltic rocks, as most of the islands we had visited. The islands were originally a French dependency, but during the Napoleonic wars they passed over into the all-embracing power of Great Britain. The colony has recently enjoyed a wave of prosperity during the II:d world war, when its products were extremely well paid. After the war came an inevitable slump, and the planters were very unhappy with the labour conditions, since wages after the war had risen considerably.

The chief of the education department, Dr. GILES, motored us on a sightseeing trip round the island. According to tradition a treasure trove, accumulated in the 18:th century by renowned pirates, is hidden somewhere in the caves. It was just then sought after by treasure-hunters, so far without results.

In the Seychelles our geologist, Mr GUSTAF ARRHENIUS left the expedition on a month's leave of absence, travelling by steamer and airplane back to Europe. When he rejoined the expedition in Suez he announced that he had married, which showed what consequences a leave of absence from an expedition may have.

Also on Mahé Dr. ERIKSSON undertook a bothanical excursion up into the hills and returned on board with specimens of the island flora. Another excursion he undertook with the aid of the ship's motor-launch was to the island of Praslin where he intended to study the remarkable palm tree, *Lodoicea seychellarium*, of which only a few trees grow on Mahé. They carry the giant double coconut, called »Cocos-de mer» which has been the subject of much super-stition and many phantastic tales. Their origin was unknown until about 200 years ago when they were still supposed to grow under water on coral reefs! Their content was considered to be an antidote against various poisons and they were, therefore, much sought after and deman-ded high prices, poisoning being in earlier cen-turies almost a professional malady amongst orientals of higher ranks. The only nuts avail-able in those times were such as had been carried by surface currents from their unknown place of origin. The nuts are the largest fruits known, weighing up to 25 kgs. In our present time the shells have obtained sales value as nature-made gourds for Mohammetan pilgrims

Fig. 87. The Coco-de-mer.

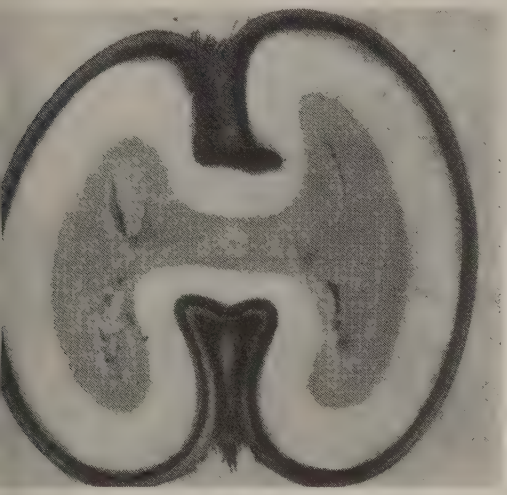


Fig. 88. Coco-de-mer cut through.

) Mekka, who are forbidden to make use of
:tefacts for this purpose.

Amongst other advantages the Seychelles
ffer that of being perfectly free, not only from
oisonous snakes but also from mosquitoes,
hich are a great plague on most other tropical
lands. They great possibilities of becoming
frequented tourist resort, provided the
ip communications with India and East
frica, at present rare and irregular, can be
nproved.

With great regret we had to leave this
iarming place, since we were already behind
ur schedule and the northwesterly Indian
cean was waiting for us.

From Port Victoria to Suez

On April 15:th the »Albatross» left the idyllic
ort Victoria and dropped its anchor some 10
autical mils outside the harbour, waiting for
ie motor-launch with Dr Eriksson and his
ompanions. They had been making a most
uccessful trip to the island Praslin where the
odoicea palm grows in abundance. Eriksson
ad made friends with the owner of the largest
lantation on the island and had from him
eceived a nice collection of the gigantic nuts,
ome of which were consumed on board.

In the morning of April 16:th we started on a northerly cruise for the straits of Babel-Mandeb. As passengers we had on board 4 large tortoises acquired in Port Victoria.

The weather as well as the bottom configuration offering good prospects for coring work, a core 5½ metres long was raised from a depth of 4 360 metres. It contained a calcareous clay, lightbrown in colour, which held numerous fragments of foram shells. On the following day, April 17:th, a much longer core was raised from a depth of 4 860 metres, its length being 11½ m. The uppermost metre consisted from calcareous clay with foram shells. Between 130 and 175 cms there were flames of different colours, whereas from 175 cms down to 300 cms the sediment consisted from nearly lime-free clay, superposed on a thick layer of calcareous clay, rich in organic substance. Still further down there was foram sand, and below that again a calcareous clay with plenty of organic residue.

The cores raised further north, out of depths exceeding 5 000 metres, varied in length from 10 to 11 metres. The sediment was again calcareous in character, with occasional layers of foram sand. The organic substance became more evident and exhaled a smell of sulphuretted hydrogen.

The oceanographic series taken to the north of the Seychelles did not show any remarkable features in the distribution of the various properties of the water, until we had reached the 10:th parallel north. There a distinct decrease in the oxygen content was manifest, with a minimum in 143 metres depths as low as 0.24 ml/L or less than 5 % of the saturation value. Only below 1 200 metres the oxygen content began to increase over 1.0 ml/L but near the bottom in 2 375 m, it was still not more than 2.13 ml/L. Also at the following station, taken in N 12° 10′, E 45° 17′, there was a pronounced drop in oxygen content below 100 m with values less than 1 ml/L down to the bottom in 900 m. Further north the oxygen content increased

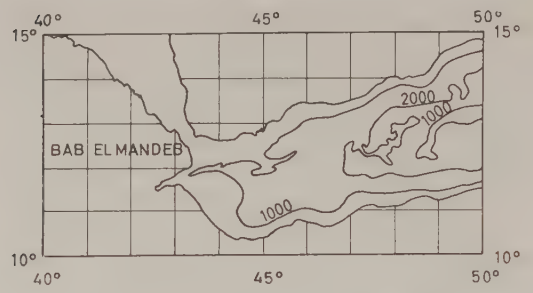


Fig. 89. Depth curves near Babel Mandeb.

considerably in the upper layers but continued low near the bottom.

On April 26:th we had passed the latitude N 12° and found there a much reduced depth. In a core raised from 830 metres, 11 m long, the sediment consisted from greenish mud with an admixture of desert sand, the smell from H_2S being quite pronounced. We were now approaching the Red Sea, where aeolic sand, carried seawards by desert storms, began to form a normal admixture to the sediment.

In the Red Sea evaporation has a dominant influence on the oceanographic situation. This evaporation is counteracted by the inflow of surface water from the Indian Ocean through the Straits of Babel Mandeb. If the treshold there could be raised from its present maximum depth of 200 metres up to the surface, cutting off the influx from the Indian Ocean, the Red Sea would, within a few centuries, become converted into a salt lake, its water ultimately reaching the high salinity characteristic of the Dead Sea. Once a difference in level between the ocean and the Red Sea surface of a few hundred metres had been attained, the ocean water, admitted through a channel and acting on turbines would be able to generate several hundred million HP of hydro-electric power and, in addition, several thousand million tons of sea-salt might be obtained annually. At present the costs of building and maintaining such a huge damm are prohibitive, apart from the nautical and political complications that would arise.

The seismic experiments carried out in the western parts of the Indian Ocean did not as a rule give any indications of sub-bottom reflexes. To the east of Port Victoria over depths of about 4 700 metres reflexes from 75 and 13 metres below the sediment surface were recorded. After leaving Mahé we recorded reflexes from 120 and from 90 metres respectively. Judging from these very scanty measurements the thickness of the sediment layer accessible to measurements by the reflexion method used from the »Albatross», is quite as small in the Indian as in the Pacific Ocean.

On the other hand, numerous instances of »animal noise» were recorded on the seismigraphs, especially in the vicinity of the Seychelles. There the shallow banks seem to harbour a multitude of fish, perhaps giving promise of future rich fishing grounds in tropical waters.

The weather, which so far had been very favourable for our work, took a turn for the worse, after we had entered the Red Sea. A strong and persistent contrary wind started blowing from the NW and reduced the speed of the »Albatross» below 4 knots. This was unfortunate for me personally, since I had intended to leave the ship in Suez and travel by plane to London and Göteborg for conferences with the British Admirality and with the owners of the »Albatross». Having already by wireless booked a seat in the Cairo-London plane for a certain day, I ran considerable risk of missing this reservation.

On the advice of Captain KRAFFT I. therefore asked to be put ashore in Port Sudan, where we made a landing on May 1:st. I intended returning from Sweden, to join the expedition in Monaco in the end of May. Dr KULLENBERG agreed to act as scientific leader of the expedition in my absence. I am much indebted to him for the information on the cruise and the work in the Red Sea and in the Mediterranean set out in the following.

Having left the »Albatross» in Port Sudan I found that all seats in the bi-weekly plane

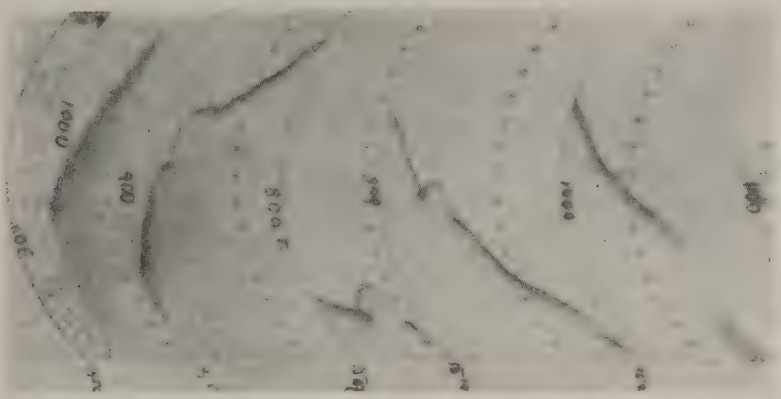


Fig. 90. Echogram from the Red Sea.

iiro were booked. I was therefore obliged to avel by railroad to Waidi Halfa on the Nile id from there by a steamer to Shellal, where I ook the train to Cairo in order to reach my ane to London.

The cruise through the Red Sea was uneentful. The nature of the bottom, uneven and iostly hard, prevented any extensive coring perations. Of the cores raised in the Red Sea ne first two, from depths of about 1 200 metres, ere each 11 metres long and consisted from alcareous ooze, rich in organic matter and iving off a distinct smell of sulphuretted ydrogen. The colour of the sediment was reenish and a stratified structure was evident. Moreover they contained also fairly large calareous concretions.

A third core was raised from a depth of 1 830 metres, but was only 2 metres long, the corer having been stopped against a hard bottom of calcareous rock. The sediment was semiliquid and not suitable for stratigraphic investigations. The fourth core, taken from a depth of 860 metres was still shorter and contained calcareous ooze with a considerable admixture of sand. It also smelt strongly from H_2S and in its lowest part held several large concretions.

The echograph drew a very rugged bottom profile through the Red Sea. Already before I had left the ship in Port Sudan I took her on a short detour to the east, near the island of Jeb Teir, where Dr KUENEN on his way to the East Indies on board the »Snellius» had by echosoundings found a very pronounced »scarp». By means of our more perfect recording echosounder we succeded in locating the same scarp which is reproduced in the main profile of Dr KOCZY's paper in Volume III of this Report. The rugged bottom made it, however, impossible to carry out any successful seismic experiments revealing sub-bottom echoes.

The Mediterranean

From Suez to the Strait of Messina

In several respects the Mediterranean is a unique inland sea, communicating with the Atlantic Ocean only through the very constricted Straits of Gibraltar. Its eastern parts are at present dominated by a very intense evaporation, due to their being surrounded by countries of an almost desert-like climate and a corresponding lack of fresh water affluent, with only the Nile as a large river and, in addition, an altogether insufficient rainfall to compensate for the intense evaporation. Within a few thousand years the Mediterranean would become converted into a salt-water lake resembling the Dead Sea, were it not for the oceanic inflow from the Atlantic through a strong ingoing surface current of seawater, compensated

by an outgoing bottom current over the treshold at Gibraltar, which transports oceanwards more concentrated and relatively warm water.

This is the product from the evaporation from the surface of the eastern Mediterranean, from which the descending salter water gives to the lower layers in the Mediterranean a higher salinity and a higher temperature, 12° to 13°, than in other parts of the oceans. Such is the water balance of the Mediterranean under present climatic conditions.

During the great glaciations of Quaternary Time the climatic conditions were much different from now. The whole climatic belt, including the travelling cyclons from the Atlantic, was then shifted to the south, and desert North Africa enjoyed at times pluvial periods with abundant rain. The south European glaciers descending from the north must, through their melt-water, have depressed the temperature of the Mediterranean surface and greatly influenced its vertical circulation and the marine life it harboured.

In addition to this the bottom configuration in the Mediterranean is generally assumed to have undergone considerable changes in recent time, especially in the north-eastern part. Thus the Aegean Sea and the straits leading into the Black Sea are assumed to be of a comparatively recent date. Furthermore, the many volcanoes in the Mediterranean region, many of which are still intermittently active, have left their marks in the shape of volcanic ash-layers intercalated in the bottom deposits, and the same may be said of the sand-carrying storms transporting sand from N Africa far out into the sea.

Already during our preliminary test cruise with the »Skagerak» in April and May of 1946 we had, in the cores raised from the bottom of the western Mediterranean, found signs of these various activities and we naturally expected to find evidence of the same kind from the »Albatross».

It was hoped that in the long cores raised near the Nile delta there might be found stratified sediments, resembling the varved clay in northern Scandinavian estuaries, possibly also layers of sand, carried seawards by the Nile during the pluvial epochs. In the more northerly and deeper cores one would expect to find signs of the varying surface conditions and their effects on the plankton organisms and on the conditions of the bottom layers, which are at present well aerated and only occasionally display signs of lack of oxygen.

Unfortunately time did not permit of extending the cruise to the northeastern Mediterranean, especially to the Aegean Sea, where violent volcanic activity during the last few thousand years must have left marks in the bottom deposits.

After passing through the Suez Canal and having various repairs to our equipment carried out in mechanic workshops at Suez, the »Albatross» started on her Mediterranean cruise on May 14:th 1948.

The first coring operations were carried out in the region off the Nile delta, but the results were disappointing. The very high rate of sedimentation of the mud suspended in the water from the Nile, accelerated by the salting out effect on the finer sediment particles through the high salinity of the Mediterranean water, made it impossible to reach down to more ancient strata, in which traces from pluvial climatic conditions might have been expected to occur. The first few cores raised consisted largely from calcareous ooze mixed with organic matter, which gave off a smell of sulphuretted hydrogen. Foram shells, pteropod shells and fine sand were also present, together with large calcareous concretions.

On the other hand optical investigations of the different water strata, carried out by JERLOV afforded an interesting picture of the variable concentration of sediment particles in the different water layers, as is shown here in fig. 91, taken from JERLOVS paper in Volume III, Fasc. II of this Report. It demonstrates beautifully the efficiency of his op-

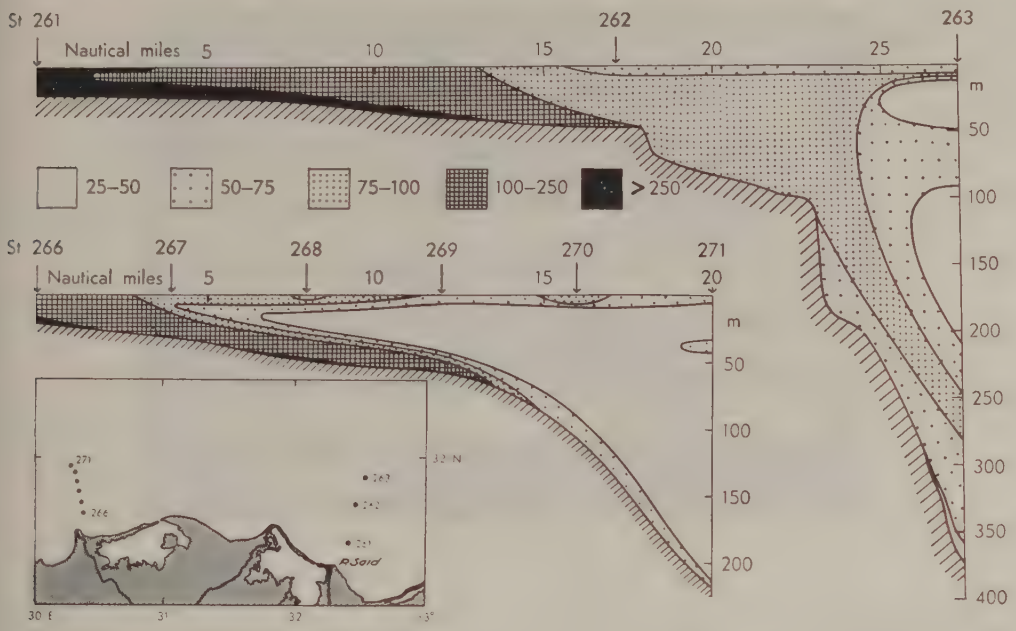


Fig. 91. Particle distribution in two vertical sections off the Nile delta (Vol. III, fig. 3, p. 79, JERLOV).

al method for obtaining a rapid survey of ne complicated hydrographic situation in a ver estuary.

Further to the north and in greater depths he cores raised became more interesting. Thus he core n:o 184, raised at Station 272 from a epth of nearly 1 200 metres in N 32° 12′, E 30° 13′, over a length of nearly 6 metres, isplayed abrupt variations both in the content f lime and in the colour of the sediment. There ere several layers of very dark sediment, rich n organic matter and giving off a smell of H_2S, indicating lack of oxygen at the time when he layer was formed. As a rule, confirmed also y finds in the following cores, such dark-green o nearly black layers were also rich in large oram shells.

Still more interesting was a following core, :o 187 raised from a depth of 2 500 metres to he SW from Cyprus in N 33° 59′, E 31° 02′, ength of the core nearly 9.6 metres. A thin op-layer consisted from soft homogeneous clay ich in fine sand, but already in a depth of from 0 to 41 cms there was a layer 1½ cm thick, ontaining colourless fragments of volcanic glass, rich in airbubbles, with a fairly low refractive index (n = 1.51) as measured by O. MELLIS of Stockholm who has investigated some of the ash-horizons in our Mediterranean cores (MELLIS 1954). He assumes this ash - layer to be derived from the catastrophic outbreak of the island volcano Santorin, which has been tentatively dated to between 1 800 and 1 500 BC and which, through accompanying devastating earth-quakes, occasioned a severe set-back to the Minoan civilization on Crete. Accepting this dating as correct, the rate of sedimentation for the uppermost 40 cms in this core should have averaged somewhat less than 10 cms in 1 000 years, a relatively low value compared with that assumed for other Mediterranean cores.

A lower ash-horizon was found in the same core in a depth of 88 to 89½ cms below the sediment surface. This ash was, however, different from that in the upper layer. The volcanic glass was free from airbubbles and its refractive index was higher, (n = 1.52). MELLIS for this reason ascribes a different origin to this lower ash-layer as not being a product of the same catastrophic outbreak of Santorin. Also

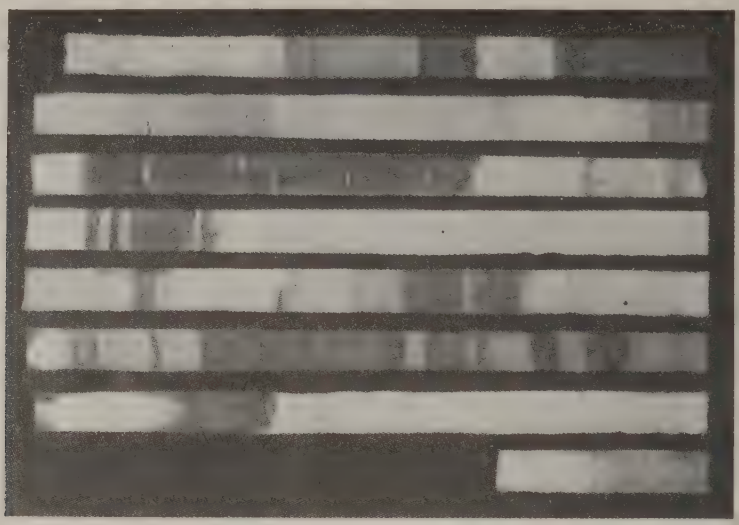


Fig. 92. Stratified core from Cyprus.

in this core a number of very dark sediment layers, rich in organic substance and in large foram shells were found, intercalated with layers of much lighter colour of calcareous ooze.

The next core, n:o 188, taken further west, at Station 275 in a depth of 2 800 metres, also contained two layers of volcanic glass of the same two types, but situated in considerably greater depths below the sediment surface, viz. in 146—151 cms and in 191—192 cms respectively. Assuming the upper layer to be also derived from the Santorin outbreak of 3 500 years ago, this would make the average rate of sedimentation during those 35 centuries as high as 40 cms in 1 000 years. There is, however, the possibility that this ash-layer may have become covered by a slumping of sediment down to the trough from which, according to our echograms, this core had been raised. The volcanic ash 191—192 cms below the sediment surface, is of the same type as that found in the lower layer of the former core, n:o 187. It is interesting to note that the difference in level between the two layers is nearly 50 cms in the former core and just over 40 cms in the latter core. Assuming the average rate of sedimentation between the two ash-layers in both cores to be 10 cms in 1 000 years, the difference in time between the two outbreaks would be from 40 000 t 50 000 years. This estimate is, of course, highl tentative.

The uppermost 70 cms of core 188 consiste from dark sediment rich in organic matte containing also small sand particles. A simil dark sediment with organic matter was agai found between the levels 300 and 340 cms, an was repeated further down in the core by severa dark layers intercalated by calcareous ooze lighter colour. Evidently there must hav occurred epochs in the history of the Med terranean when the state of oxygenation of th bottom water has been different from presen time. (KULLENBERG 1952).

The echograph drew steady curves along th greater part of the Mediterranean route, whic proved of great value for the coring wor especially to the south of Crete, where ver steep inclines were encountered, likely to hav lead to submarine land-slides (»slumping») wit a reshuffling of the sediment layers.

The greatest depth in the whole Medite ranean was found in 1891 by the Austrian nav ship »Pola» and, therefore, called the »Pola Dee with 4 400 m in N 35° 45′ E 21° 46′. Althou the »Albatross» passed within 1 nautical m from this position the greatest depth record

l. our echograph there was less than 4 000 ·tres (3 995 m in N 35° 45′ E 21° 45′). The ·eatest depth recorded in the neighbourhood, ·nautical miles to the SE of the »Pola Deep», ·s 4 231 m. A still greater depth of 4 342 m · s recorded earlier, in N 34° 25′ S 26° 09′, just ·ith of Kupoho Nisi off SE Crete. This deep we · re inclined to consider the very greatest depth far recorded in the whole Mediterranean.[1]) In Core 189 raised at station 276 from a depth 2 664 m with a core length of 8½ m there ·re again two layers of volcanic ash, the upper-·ost in the very surface was 2 cms thick, the ·wer one was found 1 metre deeper down, in 2½ — 104 cms. It is to be assumed, that ·e high level of the upper ash horizon which ·ellis, on account of the character of its volcanic ·ass also ascribes to the Santorin outbreak, ·ay have been laid bare through the removal · an upper, more recently deposited layer. ·here is, however, also the possibility that the ·p-layer may have been lost in sampling. ·therwise the core consists chiefly from light-·loured calcareous clay mixed with sand and ·ram shells, whereas layers of dark green sedi-·ent rich in organic matter are rare.

In most of the following five cores 190—194, ·ised from depths of between 2 100 and 3 600 ·etres, one or two ash-horizons were found in ·epths below the sediment surface varying from to 206 cms. Where two such horizons were ·esent, the upper one had the same character · those ascribed to the Santorin outbreak. The ·wer (or the single) ash horizon was of the ·her type already described. The same applies · core 196 raised from Station 285 to the W of ·ete at N 35° 41′, E 21° 50′, depth 4 270 metres, he greatest depth in the Mediterranean from hich a core was raised). Here a single ash-

[1]) The depth of 4 623 meters marked in the Monaco ·p of 1931 N E is ascribed to a sounding by the German ·iser »Berlin» in December of 1929 according to a com-·unication from Commandant H. Bencker in the In-·rnational Hydrographic Bureau of Monaco, comfirmed · a communication from Dr Böhnecke, Director of the ·eutsches Hydrographisches Institut in Hamburg.

Fig. 93. Volcanic ash in cores, Mellis.

horizon was found 126 cms below the top of the core.

Figure 93 is reproduced from Mellis' paper and shows his attempt to interconnect the different ash-horizons he has investigated from the eastern Mediterranean. Otherwise the sediment in these cores largely consisted from light-coloured, sometimes multicoloured, calcareous ooze containing foram shells and fine grains of sand. Occasionally dark-green layers, rich in organic remains were found, especially in the lower parts of the cores. They rarely exceeded a few cms in thickness, indicating that the state of stagnant bottom water, poor in oxygen, which probably caused them, has been of relatively short duration.

From Crete onwards to Sicily the cores raised were of much the same character as those already described. Mellis' preliminary investigation of these cores did not reveal any noticeable layers of volcanic ash. The two last cores taken before the »Albatross» entered the Strait of Messina, Core No 199 Station 288, and Core No 200, Station 289, showed more frequent layers of sand, intercalated in the light-coloured calcareous ooze. Only Core 200, which was relatively short and raised from a depth of 2 050 m, showed in its upper part a thick layer of sand with rounded edges, presumably of desert origin. The darkish sediment below the sand gave a strong smell of H_2S.

The Strait of Messina to Monaco

Passing through the Strait of Messina into the southern part of the Tyrrhenian Sea the Albatross Expedition was afforded the unique spectacle of seeing a volcano in eruption. It was the island volcano Stromboli, otherwise known for its almost clock-like regularity in sending up small clouds of ash, which has now for several years given vent to much more spectacular eruptions of redhot lava, coursing down to the sea from the slopes of the mountain. Approaching the island as close as Captain KRAFFT found it safe, the fiery display made an overwhelming impression on the staff and the crew of the »Albatross». Having had so much to do with layers of volcanic ash in sediment cores, due to eruptions thousands of years ago, it gave an additional interest to these finds to watch an active volcano in operation.

The first core raised in the Tyrrhenian Sea with the number 201 at N 39° 48′ E 13° 48′ in a depth of 2 170 m had a length of 11½ metre. The sediment was multicoloured. It had a layer of very dark sand in a depth of almost 8 metres below the sediment surface. However, the sediment appeared to have become largely reshuffled and was therefore not considered to be of any greater stratigraphic interest.

The next core raised was much more important. It was taken at Station 295 and obtained the number 205 in our catalogue. It was raised from a depth of 3 160 m in N 40° 1 E 12° 22′. Its length was nearly 18 metres, a new record for the expedition. The position coincided closely with that from which our longest and deepest core had been raised during the expedition with the »Skagerak» in May 194 After our return to Sweden this core was handed over to Professor NORIN of Uppsala, who has devoted several years of labour to a very detailed examination of the core, the results from which are being published in a later volume of these Reports. From a preliminary report, published by NORIN in Swedish in »Stat tens Naturvetenskapliga Forskningsråds Års bok» for 1952/53, the following short summary is here included (NORIN 1954).

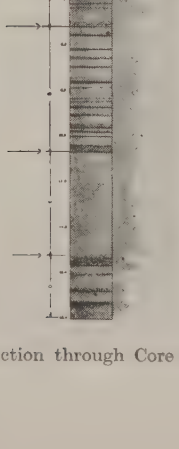


Fig. 94. Section through Core 205. (NORIN).

Figure 94 gives a graph, taken from NORIN report, which shows the more important features of this remarkable core. The curve to the right in the figure shows the variations in lime content along the whole length of the core displaying very pronounced minima, most of which coincide with layers of volcanic tuff.

The normal pelagic sediment, which constitutes the main part of the core, is a calcareous pelite, the clay component of which consists of several clay minerals of montmorillonoid type of illitoid type and of chloritic character.

In the stratigraphical sequence of the core four main divisions are to be distinguished designated by the letters A, B, C, and D the section. The lowest one, D, contains thick layers of trachytic tuff, consisting mainly of volcanic glass and pumice, the chemical composition of which characterizes the magma type as pilaskitic. Division C consists exclusively of pelite with only faint traces of volcanic activity. Division B is dominated by several thick sandy beds of mixed terrigenous and volcanic material, with the character of turbidity-current deposits. These currents originated on the slope of a submarine mount 700 m high which rises 2½ kms to the WNW from the

ing station. Division A, the top part of the re, registers intensified volcanism with two ges of extremely intense activity, represented thick pumiceous beds at — 5.2 and — 1.7 tres. The earlier of these stages furnished hly pottasic lava, the later, again, lava of laskitic type, similar to those of Division D. The very difficult problem of correlating the ferent volcanic beds in this core with known tbreaks of Calabrian and other volcanoes, is t yet solved. NORIN's very searching studies ay be hoped to shed light also on this extrely important problem.

In the meanwhile a pollenanalytical study of mples from the same core has been confided a renowned expert on the Italian pollen ra Professor E. TONGIORGI in Pisa, but his port has so far not been received.

From this last, highly successful, coring eration in the Tyrrhenian Sea the »Albatross» llowed first a northerly and later a northesterly course towards Monaco, where the ip entered the harbour on May 28:th.

Days in Monaco

Monaco had become famous as a centre of ceanographic research under its late sovereign ler Prince ALBERT I of the ancient house f Grimaldi. After conducting a number of uises with his oceangoing yachts from the iddle 80:s until the first years of this century, e Prince built his magnificent Musée Océnographique on the crown of the steep Monaco ock with a splendid view over the Medirranean. In this museum are collected the ophies from his cruises in the Mediterranean nd in the N Atlantic Ocean, including also an nrivalled collection of the most important struments and gear used in deep-ocean reearch for more than a century. The museum ffords laboratories for scientists and also beautiful aquarium. It is a great attraction oth for scientists and for tourists visiting the ivièra.

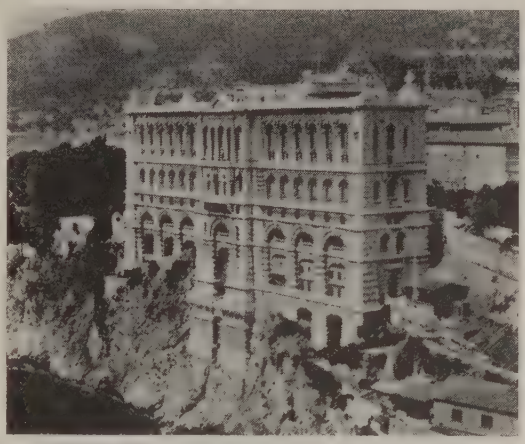


Fig. 95. The Musée Oceanographique.

Into the beautiful harbour of Monaco the »Albatross» made a stately entry in the afternoon of May 28:th, recieved by a great number of spectators including also the wives of several members of the Expedition staff, who had travelled from Sweden to Monaco for a few days' meeting with their husbands.

Together with my wife I had myself reached Monaco from Sweden on the preceding day. To my great joy I was accompanied from Göteborg by two of the generous supporters of the Expedition, Major and Mrs. H. JACOBSSON of Göteborg. All of us had a most splendid reception in Monaco where the Government of the Principality, its ruler Prince LOUIS and his grandson the Hereditary Prince RAINIER, its present ruler, and also the Director of the Musée. Commandant ROUCH and his staff as well as the chiefs and officials of the Bureau Hydrographique vied with each other in showing a charming hospitality to the visitors from Sweden.

Beside the many festivites to which we were invited during our stay in Monaco we had the pleasure of taking out some of the renowned oceanographers residing there, as well as representatives of the British Discovery Expedition, on a short cruise off the coast of Monaco. During this cruise Dr KULLENBERG demonstrated his piston corer. Although a strong »mistral»

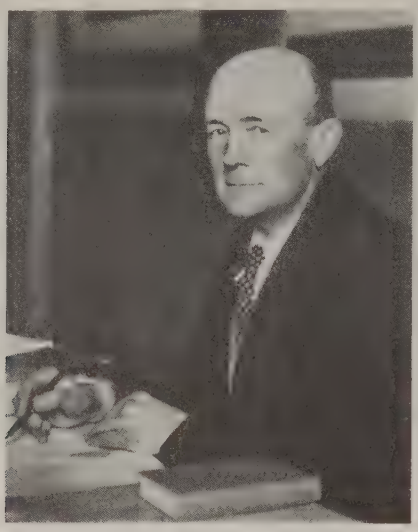


Fig. 96. Commandant J. Rouch.

was blowing with a wind velocity sometimes approaching 20 m/sec., Kullenberg successfully raised a core over 8 metres long from a depth of 2 230 metres. This feat proved to our visitors that the piston corer is not, as some of them apprehended, a fair-weather instrument which can be used only in a very moderate breeze. The core obtained consisted from soft clay, blueish in colour and containing fragments of calcareous shells, intercalated with several layers of dark sand rich in organic remains.

Afterwards Professor Weibull who had also travelled down to Monaco in order to join the expedition there, demonstrated his seismic method for measuring the thickness of the sediment layers.

Returning into the harbour of Monaco against currents and waves set up by the strong mistral, Captain Krafft of the »Albatross» displayed a smart feat of seamanship, which evoked compliments from the two admirals on board, Admiral Nares and Admiral Nichols It was on the whole a satisfactory demonstration.

During our stay in Monaco the science staff of the cruise seized the opportunities of conferring both with Commandant Rouch at the Musée and with Admirals Nares and Nichols and Captain Bencker, the chief assistant, a the International Hydrographic Bureau. W undertook to send to the Bureau extracts fro our echograph soundings, which could be use in the next issue of the Carte Bathymétriqu Génerale des Océans, a promise which wa faithfully kept.

In Monaco a further change of personel i the staff took place. Most important was tha Dr Nybelin came on board to direkt th biological work. Our chemist Mr Bruneau whom we had »on loan» from the health autho rities in Stockholm, was obliged to return t his routine work there. In his place we wer fortunate to enlist a clever young chemist fro the Chemical Institute of Uppsala, Mr T Karlsson, who did excellent service on board th »Albatross» during the remainder of the cruise

The members of the Expedition and especiall the young apprentices utilized to the full th opportunities for viewing the Museum, th aquariums, the »Jardins Exotiques» and othe sights offered by the Principauté of Monaco

Owing to unfavourable weather reports Cap tain Krafft adviced us to put off the departur from Monaco by another day, an advice whic was duly followed.

The Atlantic Ocean II

From Monaco to the Cape Verde Islands.

Already on the first day of our continue cruise from Monaco, June 5:th, an attem was made to raise another core. In this attem we were not successful. The coring tube w broken against a hard bottom and almost a the stainless-steel lining tubes it contain were lost. This made us defer the next cori attempt until we came close to the Balea Islands, where a core n:o 209, 10 m long w successfully raised from a depth of near 2 600 metres. The sediment in the upp layers consisted of fine homogenous clay a yellowish colour. It was fairly rich in

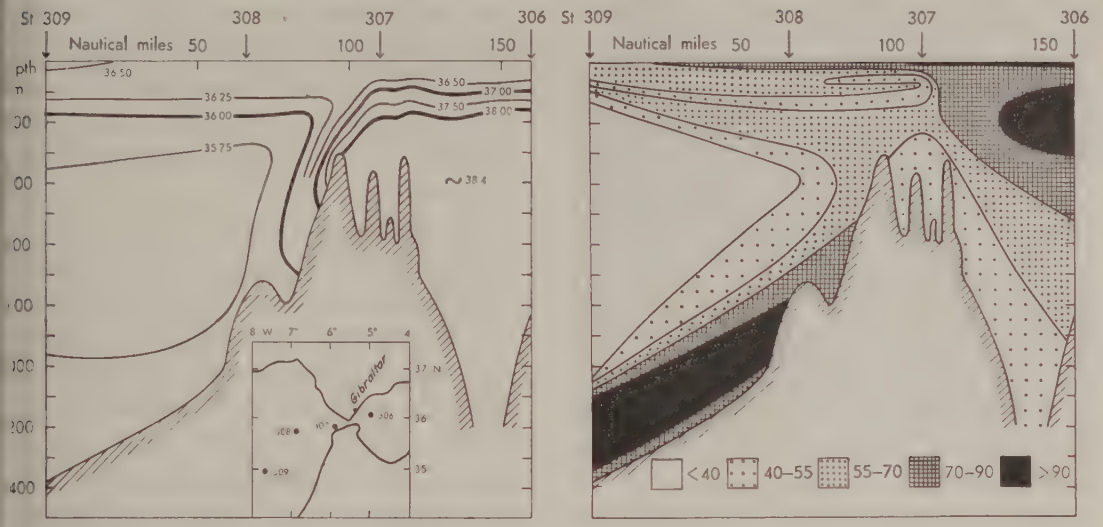


Fig. 97. Distribution of particles and salinity in a section through the Strait of Gibraltar (Vol. III, p. 80).

inic remains, giving off a distinct odour of henol. In about 6 m depth below the sedi- ent surface there were numerous pteropod ells, cemented together by iron sulphide. rom 6.3 m downwards layers of fine sand ere frequent.

Professor WEIBULL made successful attempts o use an »implosion» bomb, without any ex- losive charge, so that only the hydrostatic ressure was utilized for the detonation. He ecorded strong signals from »animal noise» ut no sub-bottom echoes were recognized.

The echograph drew a remarkably smooth urve with a maximum depth of only 2 840 ietres, the depth over a course of more than 00 nautical miles keeping within the limits f ±200 metres, obviously an excellent work- ng field for future coring experiments.

In the morning of June 10:th the »Alba- ross» passed through the Straits of Gibraltar. Ve there sighted a strong flotilla of U. S. arships on their way to manoeuvres in the astern Mediterranean, a sign of the critical olitical situation then prevailing between the JSA and the USSR.

On June 12:th and 13:th oceanographic nd optical investigations were carried out in nd near the Straits of Glbraltar from the Stations 306 to 309. The results, showing the salinity and the particle content of the water, are set out in figure 97 taken from the paper by Jerlov published in these Reports, Vol III Fasc. II. The wellknown ex- change of water over the treshold across the Straits is shown in the salinity diagram with an inflow of Atlantic water in the surface and an outflow of high-salinity water from the Mediterranean in the lower strata. The other diagram shows a strong maximum of particle content, both in the surface and in 200 metres inside the Straits, and an equally strong maximum along the slopes outside the Straits. The latter maximum may be due to the scouring action of the outflowing salt water stirring up the sediment on the bottom.

The same evening we enjoyed a beautiful display of the »green ray» from the sinking sun, the fifth time this phenomenon was ob- served from our cruise. On June 11:th the Ex- pedition reached the harbour of Tangier where, to our very great regret, Professor WEIBULL had to leave us in order to return to pressing work waiting for him in Sweden. His inex- haustible good humour and resourcefullness in all technical difficulties was a great asset and we all missed him very much.

Later in the evening of June 16:th NYBELIN had his first opportunity to carry out a deep-sea trawling.

Trawlings in great depths present very serious technical difficulties. The trawl used, a so-called »otter trawl», where the two arms are spread to a width of 30 feet by wooden boards, is a highly vulnerable gear. In order to catch bottom-living fishes and invertebrate organisms it has to follow the bottom closely, but without digging into the sediment! This presupposes, that both the length of the steel cable, used for towing the trawl, and the speed at which the trawl is moving over the bottom are carefully chosen. Also the bottom itself must be smooth and plane and not present any rocks or steep slopes against which the trawl can be torn.

In earlier trawlings the choice of the different variables, length of cable, speed, and bottom depth, had been based on guesswork. Thanks to the excellent echograph on board the »Albatross», which drew a faithful profile of the bottom contour, we were able to choose a propitious trawling ground and, at the same time, keep the depth over which we were moving under continuous control. The procedure adopted on the »Albatross» was the following. When the echograph had for some time been drawing a smooth and almost level curve, our course was shifted by 180° until the beginning of the smooth bottom was regained, then to shoot the trawl and tow it along the bottom for some hours. However, thanks to experiments carried out on board by KULLENBERG, it was found possible to adjust the length of the cable so, that the trawl did follow the bottom. A successful trawling further required fair weather with only a moderate breeze and swell. With a strong current running either way it was most difficult to keep the ship moving at the correct speed. Quite frequently therefore, the trawling had to be interrupted, because either the bottom contour lost its smoothness or the wind and swell increased. Incessant observation of the angle the steel cable was making with the horizontal was necessary and, in addition, a great dexterity on the part of the navigating officer to keep the trawl in close, but not too close, contact with the bottom.

The first attempt made on June 16:th was entirely successful. Over an unusually smooth bottom, where the depth varied between 4 320 and 4 290 metres, the trawl was towed by a 6 500 m long cable for about 4½ hours and brought on deck 12 hours after it had been shot.

To NYBELIN's delight the catch was most satisfactory. There were 12 bottom-fishes with such rare finds as two *Bathymicrops regis* one *Bathysaurus mollis* and two *Nematonurus armatus*. In addition several invertebrate organisms from the bottom, 3 *holothurians*, one *Munidopsis*-like decapodous crustacean, white with orange-red eyes, 3 *polychaete* worms. But on passing down to the bottom or rising up from it the trawl had caught a number of pelagic organisms, also of interest to a zoologist, but nothing like as rare as the true bottom-living animals.

On June 18:th a core 8 metres long was raised from a depth of 4 360 m. The uppermost 170 cms consisted of calcareous clay with small grains of sand. In 173 cms there was a layer of volcanic sand with numerous large foram shells, a similar layer occurring also in a depth of 360 cm. On the following day it was blowing hard and an attempt at coring failed. The corer appeared to have tumbled over and contained practically no sediment.

The seismic experiments carried out on June 18:th and 19:th gave distinct sub-bottom echoes, indicating a sediment thickness of 100 and 60 metres respectively, values much lower than those obtained from our first Atlantic crossing. No double echoes were recorded. Strong signals, attributed to animal noise, were recorded at the former station.

On June 21:st the wind had abated. Starting

e day with coring, the 10 meter corer brought a core barely 6 meters long from a depth nearly 5 000 metres. The sediment was a ft calcareous clay with numerous foram ells and grains of sand. Near the lower end the core there was a thicker layer of sand ntaining numerous large foram shells.

An experience repeatedly made both in the editerranean and off the coast of NW Africa is, that layers of sand, presumably largely desert origin, often contained large foram ells. A plausible explanation would be, that shower of aeolic sand brings down a great mber of the forams living in the surface yers which become, so to say, prematurely posited on the bottom.

A technical complication arose from the use the steel cable, otherwise employed at ring operations, for trawling. This in- oduced an unwanted torque in the steel ble which, when it was used next time for ring, caused the corer with attached weights rotate rapidly during the descent and inter- red with the normal relase of the trigger echanism as the bottom was reached. Sev- al instances of failure to obtain a core of ll length or to obtain any core at all must be tributed to this unwinding of the steel cable. his drawback became particularly serious hen an ordinary corer of great length, 10 etres or more, was used. With a short corer ch as those of wide-bore type the complica- ons were less serious, for which reason the ide-bore corers were often used immediately ter a trawling had been carried out.

In the afternoon of June 21:st the strong ind which had prevented coring on the pre- eding day had further abated and the ttom in a depth of nearly 4 900 metres was ry flat. The trawl was shot at 2 p m, the awl reaching the bottom at 5:30, and at 30 the hauling-in began. At 2:30 in the llowing morning the trawl was on deck.

In this haul 3 bottom fishes of the genus *Chamura* were found, the largest one having a length of 77 cms, an unusually large size for a fish from a great depth. Of bottom vertebrates there was one annelide and one sponge. Besides there was a number of pelagic fishes, large and small, red prawns etc. The relatively small catch of bottom invertebrates was probably due to the bottom being much harder than at the earlier trawling station.

Fig. 98. The sand dunes at St Vincent.

On June 22 the sky, until then overcast, cleared up and the first tropical sunshine and warmth made itself felt.

Since, at the wish of Professor HADDING, we wanted to take some cores nearer to the African coast, we steered a SE-course, hoping to obtain glauconite for HADDING. On June 23:d, Midsummer Eve, a core 8 m long was raised from a depth of 3 820 m in N 20° 21′, W 20° 37′. It consisted of soft calcareous clay with numerous foram shells and an admixture of sand grains, probably desert sand.

After raising a second core near the W African coast the »Albatross» steered for St Vincent, which we reached in the afternoon of June 27:th. A rather dismal place suffering from the effects of a severe drought, said to have lasted for three years! The inhabitants looked famished and, probably for that reason, the authorities refused us permission to land on the neighbouring, larger island of St Anthony,

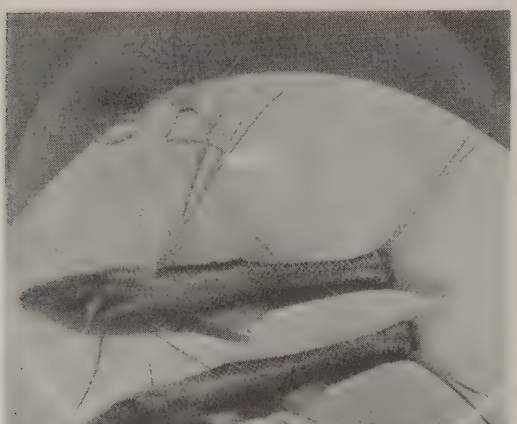


Fig. 99. Deep sea fishes.

where conditions of sanitation and of nutrition were said to be very bad, evidently too bad for being observed and reported by inquisitive foreigners.

From the Cape Verde Islands to the Romanche Deep

After passing three restful days at St Vincent the expedition continued its cruise on a southward course, heading for the Equator and for the famous Romanche Deep.

The echograph drew a remarkably smooth curve with depths varying between 4 250 and 4 900 metres. The 5 000 m depth was reached near the 13:th northern paralell, after which the depth remained between 5 000 and 5 700 metres for over 300 nautical miles, offering excellent opportunities both for coring and for deep-sea trawling. Only one seismic experiment was successful in recording sub-bottom echoes in Station 326 at N 13° 37′ W 25° 55′, where distinct reflexions were obtained from a layer situated 80 metres below the sediment surface. On the other hand »animal noises» were not observed in this region.

On June 30:th a core, n:o 223, with a lengt of only 4½ m was raised in N 15° 53′ W 25° 2 from a depth of 4 280 m. The uppermost 2 cm of this core was a calcareous ooze mixe with dark and very fine sand. Below thi layer came a thick layer of red clay wit isolated layers of sand mixed with large foran shells.

The next core, raised on the following da from a depth of 4 800 m, had a length o nearly 10½ m. Here red clay dominated, wit occasional layers of dark sand, rich in forams Also on July 3:d a long core, n:o 230, wa raised from a still greater depth of 5 500 metre with a length of over 15 m. It consisted o red clay with a layer of calcareous ooze a the very top. Further down, between 13. and 14.7 m below the top of the core, there was calcareous ooze but below 14.7 m, i. e at the lower end of the core, red clay agai dominated.

On the same day, the echograph havin registered a long stretch of very smooth bottom the trawl was shot at 4 p m and 4 hours late reached the bottom in a depth of 5 620 m with a cable length of 7 800 m. At midnigh the echograph indicated a rougher bottom, s the haul was discontinued and the traw brought safely back on deck at 6 a. m. o July 4:th.

The catch was most satisfactory and hel no less than 22 bottom fishes, one half o which belonged to the genus *Bathypteroi* whereas there was one specimen of the extrem ely rare fish *Grimaldichtys profundissimus*, fro which only one specimen had been caugh earlier by the Prince of Monaco in a dept exceeding 6 000 metres. In addition there w one *Bassozetus*, one *Leucochlamys* and near 100 bottom invertebrates. Also a number o pelagic fishes, caught while the trawl w ascending, entered into the catch. In fact th catch was a record and gave a greater numb of bottom-fishes than had been caught by a earlier expeditions working in depths great

n 4 000 metres in the North Atlantic. is fact, as Dr NYBELIN justly observes, is excellent proof of the efficiency of our uipment.

On July 6:th a core, no 233, was raised m a depth of 4 125 metres in N 07° 13′, 22° 38′ Over a total length of nearly 15 it consisted of soft clay, rich in foram shells d taking on a darker hue further down. depths of about 7 metres and 10 metres ere was very dark clay, rich in organic tter, whereas the very lowest part of the e held light-coloured calcareous ooze.

Also on the following day, July 7:th, a core about the same length was raised from a pth of 3 577 m. Its uppermost 2 cms was typical *Globigerina ooze*, superposed on red y with numerous foram shells. Further wn the sediment was of variable hue and ne-content. Below 7 m the calcareous ooze minated.

Also in the next core, no 235, 14 m. long ken from a depth of just over 4 500 m pure *obigerina ooze* dominated in the upper 15 cm followed by red clay, partly with dark streaks h in organic matter. Below 6½ m depth ere was one meter thickness of light calreous ooze, whereas in 10½ m, depth another rk layer rich in organic matter was found. he very lowest part of the core displayed a stinct stratification. On July 10:th a core ised from 5 065 m in N 02° 06′ W 20° 07′ ith a length of 14½ m showed a variable ructure, red clay alternating with *Globigerina* ze with occasional layers rich in organic atter.

The preceding summary of the cores raised etween the Cap Verde Islands and the Equar shows the variable composition of sediment und in the long cores. There is generally an pper layer of calcareous ooze followed by ay of the red clay type, sometimes, but not ariably, containing foram shells. The occaonal layers of dark sediment rich in organic atter are presumably remnants from epochs, when the oxygenation of the bottom water was insufficient for oxidising away the organic remains descending from the ocean surface. Sand layers are infrequent, although an admixture of fine sand grains to the red clay is not unusual.

That the bottom is quite well populated by bottom fishes and by invertebrate organisms is evident from the catches made with the trawl. If more time had been available for extensive trawling experiments, a much richer catch would undoubtedly have been obtained. Our purpose of visiting the Romanche deep, before the SE trade wind had gained too much in strength, made it necessary to economize with time on our way down to the Equator.

Our oceanographers carried out a section between the Cap Verde Islands and the Romanche Deep across the equatorial current-system, for future calculations of the water transport similar to the sections they had earlier carried out across the equatorial current system in the Pacific Ocean.

The Romanche Deep

One of the most interesting morphological features in the equatorial Atlantic Ocean is the Romanche Deep, situated just under the Equator between the longitudes 18° 30 and 19° W. It was discovered, one may say accidentally, by a mechanical sounding made in 1882 by the French naval survey ship, »La Romanche» on its return voyage from an expedition to the east coast of South America. The discovery was the more surprising, as it is situated in very close proximity to the Midatlantic Ridge, which here has its narrowest part, just as it turns west from an earlier northerly direction. The depth sounded was not less than 7 230 metres, the only known instant of such a great depth situated in a mid-ocean region. It is practically half-way between the African west coast and the S American east coast, the distance from both being about 1 200 kms. A few tens of

Fig. 100. Depth chart from Romanche Gap. (Stochs and Wüst.)

kilometers away the Midatlantic Ridge rises to depths of less than 3 000 metres.

During twenty years oceanographers were inclined to regard the Romanche Deep with some suspicion. However, in 1902 the discovery was fully confirmed by soundings from the German expedition with the »Gauss». Quite close to the position indicated the still greater depth of 7 370 metres was sounded. From this great depth the »Gauss» also raised a sediment core, 64 cms long, which was investigated by their geologist PHILIPPI. He found the core to consist from a top layer of red clay containin fragments of a volcanic nature. Below thi layer there were 12 cms of brown-gray clay an below that 8 cms of stratified dark gre »Schlick», i. e. hemipelagic sediment. The ver lowest 2 cm of light grey sediment containe some lime, in contradistinction to the uppe layers, which were practically free from lim Assuming this bottom layer to be *Globigerin ooze* one would conclude, that a bank covere with *Globigerina ooze* had first been raised to level in which hemipelagic sediments are dep

ited, and afterwards, in a relatively recent past, unk to its present great depth, while volcanic ruptions were occurring in the neighbourhood.

It should be remarked here, that the region long the Equator between the Romanche Deep nd St Pauls Rocks is known to have been requently shaken by submarine tremors and lso by submarine volcanic outbreaks. It is n the whole a highly unstable region, subject o violent tectonic and volcanic forces.

Curiously enough this particular region near he Romanche deep has not frequently been isited by modern research ships. In their joint aper on »Die Tiefenverhältnisse des offenen tlantischen Ozeans» in the Reports of the leteor Expedition Th. Stocks and G. Wüst n 1935 have attempted to construct a map: Hypothetische Isobaten-darstellung der Gebie- e in der Nähe der Romanche-Rinne» which is eproduced here as fig. 100 The fact that there s a break-through in the Midatlantic Ridge lose to the Romanche deep is borne out by emperature observations, which prove that here is an invasion of nearly ice-cold bottom ater from the western into the eastern tlantic Valley, where the very lowest bottom emperature are found in the immediate icinity of the hypothetical »gap». The sound- ngs so far carried out near the gap are too sparse o allow of drawing any definite isobaths for the ubmarine channel which is, however, assumed o have a treshold depth of between 4 500 and 800 metres.

To visit the Romanche Deep with the Albatross», to carry out more extensive sound- ngs there and to raise, if possible, long sediment ores from its great depth had been one of my mbitions in planning the cruise.

During the three days devoted to investigat- ng the Romanche Deep, July 13:th—15:th, e had initial difficulties in locating the naximum depth, partly owing to a strong urrent and swell from the SE, which interfered ith the echograph, when the ship was moving. nly when keeping it immovable exact depth

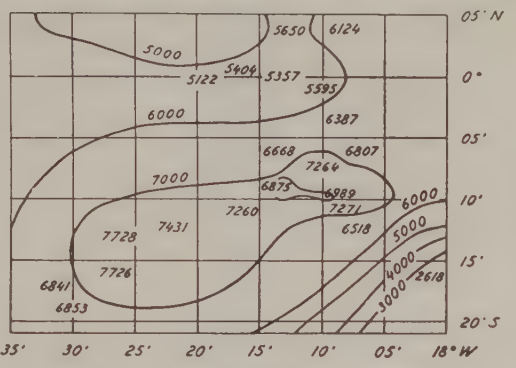


Fig. 101. Depths chart of Romanche Region.

registrations became possible, A depth of about 7 350 metres was first recorded, and after a further search, we reached a record depth of 7 728 metres in S 00° 13′ W 18° 26′, i. e. about 350 metres more than the deepest sounding taken by the »Gauss».

On July 13:th a core, no 238, 14.15 m long was raised by Kullenberg from a somewhat smaller depth, 7 315 m in a position some 20 nautical miles further to the NW. After this core, to which further reference will be made in the following, a second core was raised on the following day from a depth of 7 600 metres in N 00° 13′ W 18° 26′. Its length was, however, only 1.75 m, the corer having been stopped by a layer of coarse sand!

Only 23 nautical miles to the ESE from the maximum depth, i. e. in S 00° 16′ W 18° 03′ a *minimum* depth of 2 618 m was sounded, the very highest point in that region of the Mid-Atlantic Ridge. Over a distance of about 40 kms there is thus a difference in level of 5100 m. i. e. an average slope of about 1 in 8!

The small inset map in fig. 100 shows the trend of the isobaths near the Romanche Deep, based on the »Albatross» echograms and taken from F. Koczy's paper in Vol. III of this Report. It serves to give an idea of the topography of this very unique hole in the bottom of the equatorial Atlantic Ocean. A more detailed picture could easily have been obtained if the weather had been somewhat more favourable,

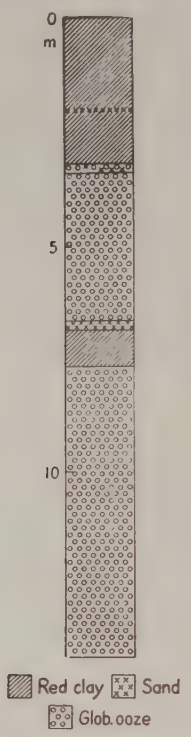


Fig. 102. Strata on Romanche Deep.

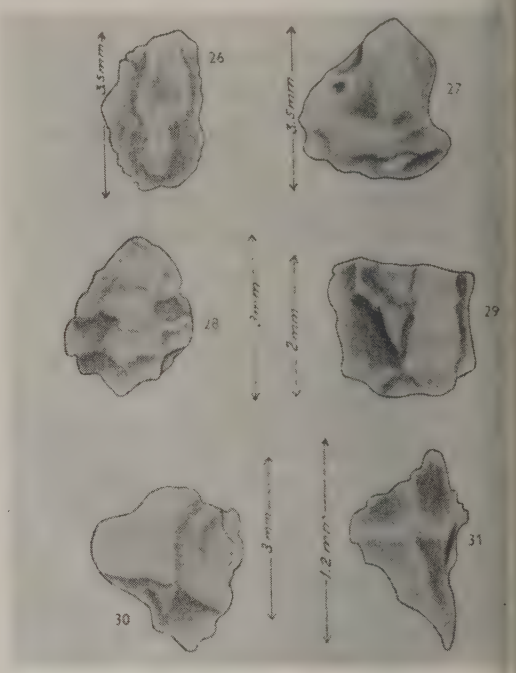


Fig. 103. Sand from Romanche Deep.

and if our attempts to establish a fixed position over the great depth by means of an anchored buoy had been successful.

Already a cursory examination of this unique core, no 238, proved it to consist from several different layers. The uppermost 320 cms of the core is a typical red clay with siliceous plankton remains from diatoms and radiolarians. In a depth of 200—201.5 cms there is intercalated in the clay a layer of sand. Between 320 and 650 cms the material is *Globigerina ooze*, superposed on a 40 cms thick layer of coarse sand mixed with foram shells. Between 690 and 800 cms there is again red clay with siliceous remains, and from 800 cms down to the lower end of the core in 1415 cms there is *Globigerina ooze*. The sand consists largely from sharpedged grains of plagioclase and pyroxene. In addition it holds fragments from basic, mainly serpentinized rock.[1])

Dr. S. LANDERGREN of the Swedish Geologica Survey in Stockholm has carried out a spectro graphical analysis of the different element present in the core, sampled for every 10:th cm Studying the distribution of magnesium and c the ferrides in core 238 LANDERGREN finds i probable, that the minerogenic material i derived from basic eruptive rocks rich in magne sium. It seems, therefore, most probable tha the sediment is derived from the submarin rocks which form the substratum below larg regions of the Atlantic bottom.

[1]) The first examination of the minerals obtained from the Romanche Deep was carried out by two French specialists Prof. A. CAILLEUX and Mlle SOLANGE DUPLAIX who described the coarse sand and rockfragmen which are totally different from other deep-sea sand and are apparently derived from a mylonization of t rocks in the Midatlantic Ridge. Figure 103 is reproduce from their paper in the Meddelanden från Oceanografisk Institutet n:o 20 1952. A more searching investigatio of the minerals in the Romanche cores has been carrie out by Dr. O. MELLIS of Stockholm who has so far onl published preliminary reports of his results. A full repo will be published in a later volume of this Report. MELL agrees with the French investigators in attributing t origin of the coarse sand and rock fragments present the cores to the Midatlantic Ridge. On the other hand h has not found any quartz in the minerals a fact whic also speaks against a terrestrial origin of the sand.

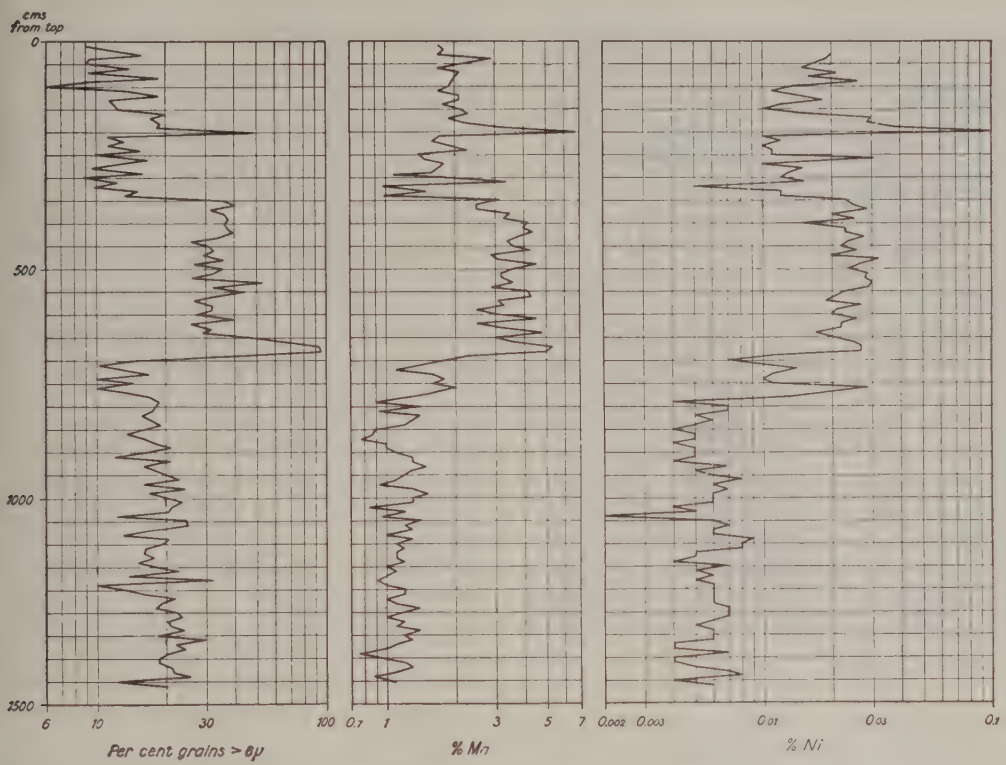


Fig. 104. Distribution of Mu and Ni in Romanche Deep.

The distribution curves for the ferrides in ıe core show very pronounced maxima nd minima especially for manganese which, owever, do not run parallel to those for iron nd the other ferrides. In his paper, published ı these Reports, LANDERGREN (1954) expres- es the view that the often very high con- ent of the manganese in deep-sea deposits ı due to a precipitation of manganese from the ea water. The present author has expressed he opinion that the very pronounced maxima ccurring in the manganese curve for core 38 are due to volcanic eruptions, the magma rom which has undergone a hydrolysis in the ottom water, furthered through the magmatic cids released at the eruption.

Both MELLIS and LANDERGREN seem to agree hat the sand in the Romanche Deep is due to ı mechanical crushing of rocks in the neigh- ouring Midatlantic Ridge, either by tectonic orces or, possibly, by a submarine explosion. The former explanation has already (in 1952) been put forward by the present author.

The distribution in the core 238 of the element radium has been measured in the Oceanographic Institute by V. KRÖLL (1955). He finds two very high maxima of radium content in the core. In the upper maximum, situated in a depth of 128 — 129.5 cms from the top of the core, the exceptionally high value of $66.7 \cdot 10^{-12}$ gr Ra per gram sediment was found. It seems difficult to explain this abnormally high content of radium, the highest so far found in any of our cores from the open ocean, except by assuming that a surface layer of high activity has fairly recently through slumping become covered by a 1 metre thick layer of older and hence less radioactive sediment.[1])

[1]) Judging from our experiences gained in the Pacific Ocean an equilibrium quantity of ionium-supported radium of 60 to 70 units of the 12:th decimal place should be normal in the surface of a sediment of a low rate of accumulation in a depth of 7 500 metres.

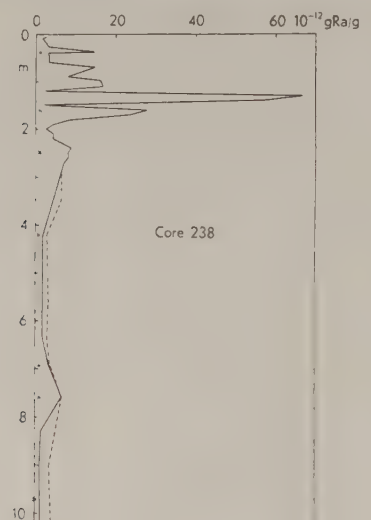


Fig. 105. Radium in Romanche Deep.

The forams in the Romanche core have been investigated by PHLEGER, PARKER and PEIRSON (1953) in their comprehensive study of the foraarms in the cores raised by the »Albatross» in the N Atlantic Ocean. They found that there were essentially no foraminifera in the upper 380 cms of the core, probably owing to a solution of the lime by the bottom water. From 420 cms downwards the Foraminiferae found are non-recent, probably of Miocene or even of Oligocene age.

In addition, KOLBE (1955) of Riksmuseum in Stockholm has studied the diatoms in the core He finds no Pre-Quaternary diatoms present in the sediment, a fact which he inclines to attribute to a solution of the silica by the bottom water, leaving no diatoms of older age observable.

Most interesting investigations on the oceanography of the Romance Deep were carried out by JERLOV (optical investigations) and by KOCZY, (geochemical investigations). A technique developed on board allowed of taking uncontaminated water-samples quite close t the sediment surface and in accurately know vertical heights over it.

JERLOV's measurements indicate the preva ence of suspended particles in different depth Apart from a strong maximum of particles i the uppermost water strata, where an intens productivity of plankton occurs, the seawat below the depth of 4 000 metres shows a increasing clarity. However, in a height of 2 metres above the bottom there is a turbi layer, rich in particles, whereas still closer t the bottom (in + 7 metres) the water remarkably clear. A similar transition in 23 r is shown by the silicate content which has ther a pronounced maximum, whereas with a sti closer approach to the sediment surface th silica content like the turbidity shows a shar decline.

The general conclusions drawn by the sam authors from their investigation, the first o this kind ever carried out in great depths, i that close to the bottom a water-layer betwee 20 and 50 metres thick is moving, apparentl without any turbulence. Over tresholds an other irregularities in the bottom configuratio turbulence arises, so that the typical gradien in the vicinity of the sediment vanishes. Thes phenomena, close to the sediment surface, ar of considerable importance for the geochemistr of the bottom water and of the sediment.

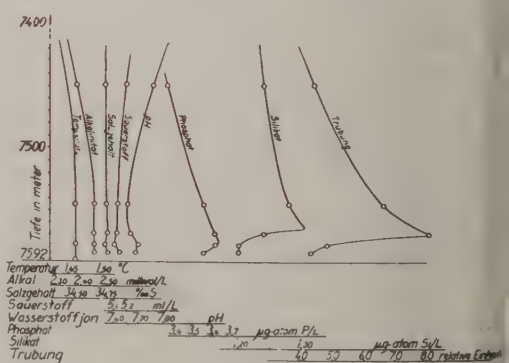


Fig. 106. Bottom water in Romanche Deep.

'rom the Romanche Deep to St Paul's Rocks

Leaving the Romanche Deep and all its still nsolved problems behind us we on the »Alba- :oss» steered to the north in order to give Dr 'YBELIN an opportunity for a much desired :awling to the north of the Romanche Deep. [ere the hypothetical break-through in the [idatlantic Ridge, the Romanche Gap is ssumed to admit the ice-cold bottom water ·om the western into the eastern Atlantic alley, where the very lowest bottom tempera- ıres are found quite close to the Equator. Such bottom current may be assumed to have an ıfluence not only on the bottom temperatures ut also on the fauna inhabiting the stream- ·wept bottom.

On July 16:th the »Albatross» reached a tretch of smooth bottom suitable for trawling. 'he trawl was accordingly shot at about 2 . m. in the early morning. In all 7 350 metres f steel cable were paid out to allow the trawl o follow the bottom according to KULLEN- ·ERG's calculations. The registered tension in he cable indicated that the trawl reached the ·ottom at 6.30 a. m. in a depth of 5 250 metres n N 01° 03′, W 18° 40′. After a haul lasting or 4 hours, during which the depth, according o the echograph, only varied between 5 250 nd 5 300 metres, the hauling-in was started at 0.30 a. m. and the trawl was on deck at 4.30 . m., i. e. the whole operation had required 4½ hours.

In the catch obtained there were 6 bottom ishes, 4 specimens of *Bathymicrops regis*, 1 of *'halinura carapina*, and one of *Porogadus* sp. In addition, and this was particularly grati- ying to NYBELIN, there were numerous bottom ıvertebrates, three holothurians, one of them ·iolet-red and very large, 25 starfishes, several ırge and small *Umbellulae*, several different iliceous sponges. The catch of these inverte- ·rate organisms can be taken as a sign of the eality of a fairly strong bottom current and

Fig. 107. NYBELIN sorting the catch.

hence also of the existence of the »Romanche Gap».

On the following day, July 17:th, the course was turned towards the west, as we intended to follow the Equator to the west. A core, number 241, 14½ metres long, was raised from a depth of 4 345 m in N 01° 10′, W 19° 50′. The sediment it contained was a calcareous ooze with numerous *Globigerina* shells. The percentage of $CaCO_2$ was in general well over 50 % and, especially in the uppermost 20 cms, exceeded 80 %. This core as well as a much shorter »pilot core», taken at the same station, was handed over to Professor J. D. H. WISEMAN of the British Museum for Natural History in London, who has devoted several years to a close investigation of this core. Especially in its upper, and hence more recent, parts WISEMAN has attempted to use the varying content of $CaCO_3$ in different strata of the core for paleoclimatic registrations, assuming that the rate of deposition of calcareous shells from the ocean surface has been in proportion to the surface temperature. In this way WISEMAN believes to have traced, from the lime content

Fig. 108. The »Challenger» at St. Paul's Rocks.

Fig. 109. Our landing on St. Paul's Rocks.

in the uppermost parts of the cores the surface temperature curve in the late Pleistocene. A detailed account of these investigations, the costs of which have largely been contributed from Swedish donors, has been promised for a later volume of these Reports.

On July 19:th the bottom profile drawn by our echograph was at first not very promising but decidedly rugged. However, the bottom profile improved in the course of the morning so that KULLENBERG took the chance of raising a long core from a depth of 3 600 metres in N 00° 30′ W 25° 38′, the length of the core, N:o 242, being a little over 10 m. The sediment was almost white in colour and consisted from calcareous ooze, in parts pure *Globigerina ooze* Further down in the core the ooze was mixed with red clay, containing large forams. A second core of the same length raised from an equal depth on the following day, also consisting from light calcareous ooze, was obtained.

In the meanwhile our oceanographers had not been idle. Every day after leaving the Romanche Deep, series of temperatures and of water samples had been taken in the greater depths and been analyzed for hydrogen-ion concentration, alkalinity, carbon dioxide, oxygen, phosphate and silicate. The salinity determinations were as usual reserved for laboratory work after our return. Thanks to these measurements the oceanographic elements in the deeper water layers along the Equator are now known in the central Altantic Ocean. The highly irregular bottom configurations prevented any sub-bottom echoes to be recorded during this part of the cruise.

No very remarkable features were recorded on our echograph except in the afternoon of July 19:th, when we passed over a submarine bank or ridge, where the minimum depth was only 1 846 metres or just over 1 000 fathoms. The depths on both sides of this ridge, between 1 400 to 1 900 metres greater, corresponded to slopes of an alpine steepness of 1: 6. Lack of time prevented us from a closer study of this remarkable rise in the bottom curve. Otherwise the depths after we had left the Romanche Deep were fairly constant, mostly 3 400 to 4 400 metres. Occasional sudden jumps, however, occurred between stretches of level bottom.

St Paul's Rocks

The only parts of the Midatlantic Ridge near the Equator which rises over the ocean surface are the small desolate islands called St Paul's Rocks. They are rarely visited by ships, but both the »Challenger» and the »Meteor» Expeditions touched there. As they are a potential danger to transoceanic navigation the Brazilian government in the early 1930:s had an automatic beacon of the Swedish Aga type mounted on the largest of the islands. However, one of the frequent local earth

uakes demolished the beacon after a few ears, since when it has been out of function nd has become a refuge of the seabirds in- abiting the rocks.

We had decided to make a landing by boat om the »Albatross», a purpose which was ccomplished, while the »Albatross» kept at respectful distance from the dangerous rocks. he landing party, comprising our Dr Eriks- on and a few members of the staff passed me busy hours on the largest island studying nd photographing bird life and making col- ctions of marine animals and of geological pecimens. The material from which the rocks re built is not, as one might have expected om the other islands on the Midatlantic ridge, olcanic but consists from ultrabasic rocks »an phanitric serpentinized peridotite with ens- tite as the dominent pyroxene», according to . Arrhenius.

The radium content, measured after our return to Göteborg, proved to be very low, as might have been expected from these highly

Fig. 111. Two young boobies.

Fig. 110, Beacon on St. Paul's Rochs.

Fig. 112. An *Umbellula*.

basic rocks, and was totaly unsuitable for radioactive age-determinations. We had hoped to obtain some evidence for the age of the rocks by raising cores from their immediate vicinity. The hard bottom and the irregular bottom profile near St Pauls made an attempt at coring too risky for our precious gear, so we had to leave the most desolate islands in the Atlantic Ocean without being able to elucidate the date of the upheaval, which raised them over the ocean surface, presumably in late Tertiary time. The screams from the indignant sea-birds we had disturbed in their lawful occupation of nesting, fishing and feeding their offspring, accompanied our retreat to the »Albatross» which continued its westbound course along the Equator.

From St Paul's Rocks to the Virgin Islands

The first core raised during this part of the cruise, on July 22:d, was from a depth of 3 200 metres in N 00° 48′, W 31° 28′. It had a length of nearly 9 metres and consisted from *Globigerina ooze* containing numerous large foram shells. Flames of darker hue and also a variable colour of the sediment was noticed further down in the core. On the following day a 10 m long core, no 248, was raised from a depth of nearly 4 600 m at N 00° 16′ W 33° 40′. Its upper parts consisted mainly from blue mud with a single layer of volcanic tuff near the 1 m depth. Between 880 and 960 cms there was a layer of fine sand. Such layers of deep-sea sand were found also in several of the following cores. They present a highly interesting problem regarding the origin of this sand.

Jerlov, through his optical analysis of water samples collected on the western slope of the Midatlantic Ridge at Station 351 N 0° 29′ W 32° 10′, 3 858 m, obtained striking evidence of the effects from bottom erosion stirring up sediment particles from the bottom there (vide figure 24 in a paper by Jerlov Vol. III No 3.)

On the same day Nybelin attempted a haul with the trawl which was a failure. The trawl bag had been torn off during the haul probably owing to it having become filled with sediment. Also the next attempt at trawling, made on July 26:th—27:th, failed the trawl having become turned inside out and tangled up. The few invertebrate animals retained in the meshes of the trawl were holothurians, starfishes and one large *Umbellula*.

A seismic experiment carried out at this station gave a sub-bottom reflex from a sediment depth of 100 metres.

The next core of interest, no 251, raised on July 25:th from a depth of 4 540 m had a length of 9½ m. Its upper layers were of red clay with intercalated layers containing forams. Between 470 and 500 cms there was a layer of sand, whereas thinner sand-layers occurred further down near the 900 cms depth. Otherwise the core contained layers of blue mud, one extending from 250 cms down to 470 cms, followed by the first layer of sand superposed on red clay.

A number of the cores raised in the western art of the equatorial Atlantic with the core umbers 248, 251, 252, 255 and 257, all from epths of about 4 500 metres, contained layers sand varying in thickness between 1 mm nd 1.5 metres! The problem of the deep-sea nd, its origin and its transportation was nsidered sufficiently important for calling to ne Oceanographic Institute in Göteborg a pecialist from the »Sedimentpetrographisches nstitut» in Göttingen, Dr F. W. LOCHER. He a pupil of the foremost specialist on deep-sea ediments in Europe, Professor C. W. CORRENS, whom we are most indebted for the interest ith which he has followed our investigations nd for the manifold help he has given. Both ne two papers written by LOCHER (1952, 1954) n this subject have been published in the »Heielberger Beiträge zur Mineralogie und Petroraphie» and are reprinted in Volume VII of nese Reports. The main results found by OCHER may be summarized thus:

The mineralogical composition of the sand s the same over the whole region from which hese five cores were raised, the extension of hich, in the direction SE to NW, is over 500 kms. The grain size of the sand increases rom the SE-to the NW. From this fact it eems probable, that the sand has been transorted by currents moving from NW to the E, i. e. contrary to the direction of the present urface currents in this region.

As to the source of the sand LOCHER assumes t to be of continental origin and probably ue to a weathering of the rocks within a mited region, from where it has spread fanke over the bottom. The sand is distinctly ifferent from that found in the Romanche eep. Of great interest are the plant remains ound in the coarser sand-layers which, accordng to Professor FIRBAS in Göttingen, are agments up to 1 cm in length from trees or rushwood grown on a continent, or on a arge oceanic island.

The foram studies made by PHLEGER et al. on the cores from the equatorial Atlantic have shown that there is ample evidence for a displacement of faunas from shallow water to great ocean depths. Thus in core 248 the fauna found between 830 and 1 000 cms consists largely from benthonic, shoal-water forams, and the same applies to benthonic forams found in the lower sections of the cores 252, 256, 257, 258 and 262. The find of a displaced shoalwater benthonic fauna in core 257, from 430 cms downwards to the bottom of the core, seems highly significant in correlation with LOCHER's observations on the sand layers in the same core. According to LOCHER the most plausible interpretation of the transportation of the sand into the deep-sea is, that a layer of weathered rock-debris, deposited near the edge of the shelf along the NE coast of S America, has become transported seawards by »suspension»- or »turbidity»-currents along the bottom. Judging from the thickness of the fine-grained deposits superposed on the sand and from what is known about the rate of sedimentation in the equatorial Atlantic, LOCHER estimates the transportation of the sand to have occurred about 200 000 years ago, an estimate which is obviously only tentative.

A difficulty with this explanation is, however, that the average slope from the part of the S American shelf, indicated as the probable origin of the sand, is very feeble, of the order of 1:200 or still less. Moreover, there are no data supporting the view, that this slope is not interrupted by rises of the bottom contour. Also the assumption, that such heterogenous material as the coarse sand with the plant remains it contains have kept together during a transport along the seabottom over more than 500 miles, appears far fetched.

Another conceivable explanation is that the sand had its origin on a large midatlantic island, now disappeared beneath the ocean surface. This assumption is not supported by any known bathymetrical facts. We must,

therefore, conclude that the origin of the deep-sea sand and its mode of transportation belong to the many unsolved problems of the deep-sea floor, problems which can only be solved through further extensive investigations in this region of the equatorial Atlantic.

The only successful trawling during the cruise from St Paul's Rocks to the Virgin Islands was made on August 3:d at N 12° 22′ W 52° 00′ in a depth of just over 5 000 metres, the trawl being towed belong the bottom for 4 hours. In the catch there were 5 bottom fishes, one *holothurian*, two large *amphipods*, and a considerable number of *Umbellulae*. Nevertheless it gives a picture of the previously unknown bottom fauna in this region of the western Atlantic Valley. It lends no support to the idea that the bottom fauna should be radically different on the two sides of the Midatlantic Ridge.

Of the four cores number 258, 262, 263 and 264 the three first had a length exceeding 10 metres. In core 258 the upper layers held calcareous ooze, whereas in its lower parts there was clay with frequent layers of very fine-grained organic *detritus*. Core 262, raised from a depth of nearly 5 500 metres, consisted in its upper parts from red clay with a low content of lime, whereas its lower parts consisted from a darker clay mixed with fine sand.

Also core 263, raised from a depth of 5 300 metres, which had a length of nearly 15 metres, was largely made up from red clay, poor in lime; intercalated in the clay was an admixture of small grains of sand with a few layers of fine sand. Core 264 was much shorter, 5½ metres long, raised from a depth of 5 300 m. It consisted from red clay of an orange-brown hue, poor in lime.

The last core raised before we reached the St Thomas island, number 267, had a length of nearly 12 metres and was raised from a depth of 2 100 m. The sediment was *Globigerina ooze* of a whitish-grey colour and apparently homogenous in structure. PHLEGER and his coworkers, however, find that most or a of the forams present in this core have bee displaced from shallow waters. Three foss species are present occurring in significa frequencies from 610 cm to at least 950 cm

The Virgin Islands

have an emotional background for us Scand navians, since it remained a Danish colo until 1917, when it was ceeded to U. S. A. T capital on the most important of the island St Thomas, has been named after a Dani queen Charlotte Amalie. Most of the stree have Danish names and there is a statue to Danish king, Christian IX:th, in the marke place. The older negro inhabitants can st speak a few words of Danish.

We were very well recieved by the promine people, who are mostly of Danish blood. first the islands were under the administrati of the U S Navy, until the U S governme took over the islands in 1930, but soon fou possession a failure from a financial point view.

The governor Mr HASTIE, at the time our visit, is a descendant from negro slav He kindly recieved us in audience. Being extremely able lawyer he had the uniq distinction for a coloured man to be nominat governor over the Virgin Islands. They ha been described as »a paradize for climate a an inferno for politics.»

One of the great problems of the Vir Islands is their lack of fresh water. V expensive »catchments» for rainwater ha been constructed on the rocky slopes of t hills. Still, water is scarce and for the »All tross» freshwater tanks, in need of being plenished, we had to pay 2 $ a ton for water supply. A novel scheme to utilize so heat for distilling salt water pumped up the top of a hill, a scheme developed at M I T, is to be tried out shortly.

We made very many friends in St Thom

ne of them, an old Norwegian bacteriologist, as kind enough to accompany me and my on on a 2 days excursion by airplane to the eighbouring island of St Croix. Its flourishing igar plantations became uneconomical in the iiddle of the 19:th century, when the Danish overnment abolished slavery on the islands. he negro slaves who had been employed in ie sugar-cane fields and in the sugar mills ere set free and — miserable, since there was o employment for them! Some of the old igar mills are still standing and have been onverted into picturesque residences by Ameri- an millionaires. Also in St Croix we were ery hospitably received, thanks to our Nor- egian friend who is extremely popular over he islands. After two restful days, spent argly in bathing costume on the splendid eaches of St Croix, we took the plane back o St Thomas in good time for the departure f the »Albatross». The most necessary over- aul of its engines had taken a longer time han anticipated and it was not until in the vening of August 16:th that the Expedition ould start again for the great depths to the orth of St Thomas.

The greatest danger threatening these won- lerful islands are the tropical hurricanes which ulminate in August, September and October. The last time St Thomas was ravaged by a urricane was in 1932, but in the year efore our visit there had been a narrow scape from a hurricane. Only in the last our it changed its course and vented its rage on Florida, where it wrought damage, mostly on military hangars, to the value of 50 million dollars.

The harbour of Charlotte Amalie is considered o be one of the few relatively hurricane-safe arbours in the West Indies, which was the main reason why we had decided to touch here instead of in one of the larger harbours on the neighbouring island of Haiti. Fortuna- ely there were no immediate signs of any approaching hurricane when we started on

Fig. 113. Dee-sea shrimps, *Nostomus*.

our northward course from the last non-European harbour visited by the »Albatross» before its return to Europe.

From the Virgin Islands to London

The greatest depth in the whole Atlantic ocean is found in the bottom of the Porto Rico Trench to the north of that island. There the USA cruiser »Milwaukee» in 1939 made a record sounding of over 9 000 metres. Our steel cables on the »Albatross» had not a sufficient length for a trawling in this enormous depth. Instead we took a northerly course from St Thomas in order to reach the prolongation to the eastward from the Porto Rico Trench, where more moderate depths were to be found.

Owing to the contrary wind and also to the reduced power of the ship's engine, we did not reach a depth exceeding 7 000 metres as soon as we had anticipated. On August 17:th at 6.30 p. m. the trawl was shot at the end of a steel cable nearly 12 000 metres long. It reached the bottom at 11.00 p. m. in N 19° 42′ W 64° 44′ and the haul was interrupted at 4 a. m. on August 18:th, the depth along the haul having varied between 7 625 and 7 900 metres. Unfortunately the wind, which had at the beginning

Fig. 114. The dredge was badly torn.

been moderate, freshened considerably, so that during the hauling-in the ship had to bear away and drift downwind at an increasing speed. Despite the severe strain on the trawl it came up whole, but wide cracks between the planks of the otter boards indicated, that the wood had been strongly compressed by the great water pressure.

The contents of the trawl were slight and at first sight appeared to consist exclusively of pelagic animals. However, a couple of worm-tubes of clay were evidence that the trawl had been on the bottom and that bottom-living organisms really do exist there. Here and there in the meshes were found small *holothurians*, unfortunately very defective. Further there were found some large *amphipods* with orange-red eyes, likewise badly damaged, and a large *isopod*, very defective, which could all be assumed to be bottom forms.

Dr Nybelin (1951) concludes his comments on this record-breaking haul by saying, that it is regrettable that this haul, carried out at least 1 600 metres deeper than any previous haul in the Atlantic, had to take place under such unfavourable weather conditions. However, it did prove that metazoans really exist at dept greater than 7 600 metres, a very considerab displacement downwards of the hypothetic »zero-line» of organic life.

A new haul with the trawl was made August 20:th in N 24° 12′ W 63° 23′ the dep there being 5 860 m, and the nature of t bottom red clay. The catch contained o bottom fish *Grimaldichtys profundissimus* whi had thus been caught in all three of t deepest N Atlantic hauls in which fishes ha been captured, but only in these three. Besid there were also some invertebrate organism present, i. a. 1 small holothurian, several lar isopods and 5 *Umbellulae*.

On August 24:th a deep oceanographic seri was taken, extended from the surface down immediately above the bottom in 5 900 metre Next to the bottom there was a slight decrea both in oxygen, phosphate and silicate, where the particle content increased to a maximu In connection with this series a number large-volume samples for the determination uranium and of radium was also taken in 2 500, 1 000, 2 000, 4 000 and nearly 6 000 metre

On August 23:d 24:th a haul was made wi the sledge trawl, mainly with the purpose obtaining manganese concretions which, accor ing to the Admiralty charts, were likely occur in this region: N 28° 25′ W 61° 05′. Th length of the cable paid out was 9 700 metr and the depth along the haul varied from 5 5 to nearly 6 000 metres.

Owing to the roughness of the bottom t sledge-trawl came up with the cross-bars b tween the runners badly bent and the large ba badly torn with all the three bags partly loo from the frame. Judging from the traces le in the bags, especially in the two extra bag which had not been too severly damaged, t sediment was a red clay, poor in calciu carbonate but containing masses of mangane nodules and stones, as well as a number sharks' teeth. The bottom animals caught we few and had been badly crushed by the ston

d concretions. In all over 250 man-
nese concretions were found in the net-
gs of the sledge trawl, some of them
arly spherical in shape.

The echograph drew highly interesting
rves along our course from the Virgin
ands towards the vicinity of Bermuda.
ıe greatest depth recorded was 8 291
ɛtres in 19° 47′ N, 64° 55′ W. From
en on the depth remained fairly constant
tween 5 900 and 5 400 metres. From
° N onwards it repeatedly touched and
en topped the 6 000 meter mark, but
ɔm 29° 40′ onwards this did not happen.
ıe depth remained always between 5 000
ıd 6 000 met res until the 33° N, parallel
ıs reached, after which the depth de-
eased to between 4 500 and 5 500 m.
ossing the Açores Plateau a minimum depth
1 280 metres was recorded in N 41° 32′ W
° 33′. Well over in the eastern Atlantic Valley
eater depths were again met with, the maxi-
ım recorded in N 43° 11′ W 19° 41′ closely
ɔproaching 6 000 m.

By the seismic work carried out between St
ıomas and London 4 distinct instances of sub-
ɔttom echoes were recorded from depths
ɾying between 60 and 150 metres. Animal
ɔises with 12 to 31 pulses per second were
equently registered. Also a scattering layer
the water was recorded in this part of the
uise.

On August 26:th a most interesting thick core
ıs raised from a depth of 5 600 metres in
29° 21′ W 58° 09′ i. e. about 700 nautical
iles east of Bermudas. The length of the core
ıs only 184 cms owing to the many stones
e corer had encountered in the uppermost
diment layers. The sediment consisted lar-
ly from red clay and contained stones and
ncretions of a size increasing downwards.
ıe uppermost 10 cms consisted from a hard
anganese-ironoxide crust of a light-brown
lour. The material in the core was again
nded over to Professor O. Mellis of Stock-

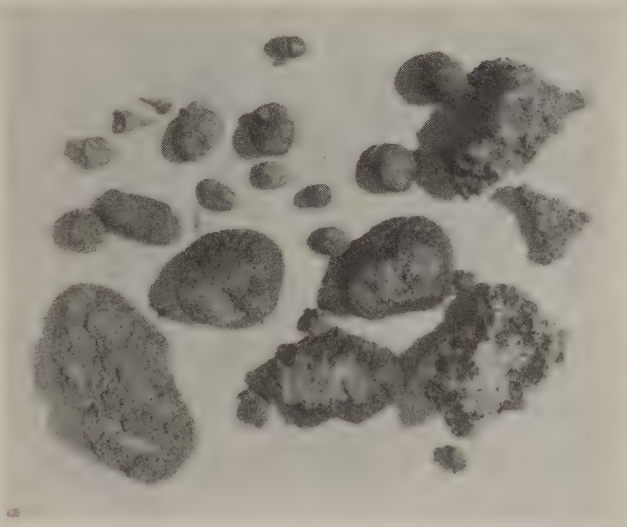


Fig. 115. Manganese nodules.

holm and we are still, since more than 5 years, waiting for his full report. From a preliminary note published by him in the transactions of the Geologiska Föreningen in Stockholm, at their meeting on February 7:th 1952 the following data are taken, based on a joint investigation by Mellis and Fredriksson 1952). The material in the stones is largely serpentinized basic rock. The larger fragments show under the microscope a transformation from plagioclase into ortoclase so that a »weathering crust» 3 to 5 mm thick is visible. The homogeneous composition of the stones and mineral fragments and their mixture with red clay speaks in favour of an origin of the minerals from the rockbed of the ocean bottom. Their relationship with the sand found earlier in the cores from the Romanche Deep strongly favour this interpretation. No fragments of quartz or of quartz-containing minerals could be discovered in these cores. It was emphasized by Asklund in the discussion following on Mellis' paper that the highly interesting tectonic deformations of the »green-stone» rocks over the Atlantic bottom should be interpreted as leading to a true »mylonizing». It is most remarkable to find among autochtonous rocks from the deep ocean floor in the Atlantic Ocean deformations of a

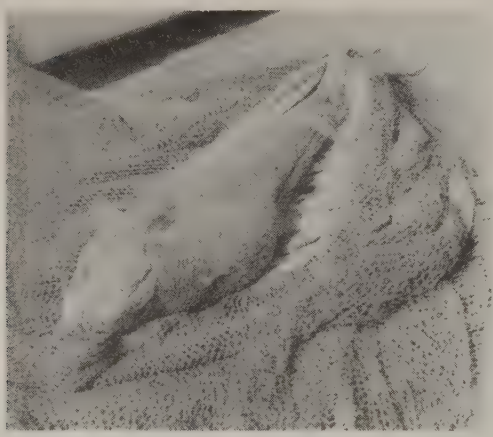


Fig. 116. Our largest deep-sea fish.

cataclastic type. This seems to prove, that also the Atlantic rocky sustratum presents signs of deformations due to horizontal movements, an example of »living tectonics» in great ocean depths.

Most of the coring operations carried out after August 26:th were sucessful. Among the more interesting of the 15 cores raised during this part of the cruise the following should be mentioned.

On August 27:th, although the echograph curve was not encouraging, a 16 m corer was sent down in a depth of 5 600 metres. The core raised was 15.6 m long and consisted in its upper layers from red clay of a brownish to grey-brownish hue. But in a depth of nearly 13 metres there came, surprisingly, 30 cms of a perfectly white layer, consisting from fine calcareous ooze with a lime content exceeding 80 %, superposed on another layer of red clay. This occurrence of calcareous ooze intercalated in an apparently homogenous red clay, must signify a sudden change in either the temperature of the surface water and/or a change in the chemistry of the bottom water, which occurred in Pliocene time, perhaps 1 300 000 or even 2½ million years ago, depending on whether the average rate of sedimentation of the upper 13 metres of the deposit has been 10 mm or only 5 mms in 1 000 years.

The two longest cores taken during t Atlantic cruise were raised on Sept 1:st and from depths of 4 650 and 4 280 metres respe ively in N 34° 06′, W 46° 12′ and N 34° W 44° 16′. The former core 19,17 m lo consisted from red clay alternating with c careous sediment, the second core, which w 18.7 m long, consisted from fine calcareous oo with occasional layers of red clay with considerable content of lime. Near the lo end of the core there were numerous foram she of large size.

On Sept 18:th the last core of the cruise w raised in N 47° 41′ W 12° 43′ from a depth nearly 4 300, m, its length being 5.4 metr The sediment was foram ooze of a greyish h but in the middle of the core there was a p ceptible admixture of sand and near its lo end manganese concretions and sand.

An occasion for trawling had been offe already before leaving the western Atlan Valley. On Sept. 7:th the trawl was shot N 40° 35′ W 35° 24′ over a depth of abo 4 600 metres. The catch consisted of 9 bott fishes, one specimen of *Nematonurus arma* having the impressive length of 83 cms. addition there were 6 specimens of *Bathypter* and 1 of *Leucochlamys* plus several holothuria and *Umbellulae* together with other botto living invertebrates. The catch was the rich during the whole expedition, when consider the number of species of bottom-living anim caught. This NYBELIN attributes to the f that the trawl had worked across a ridge on bottom.

A last opportunity for trawling, this time the eastern side of the Midatlantic ridge, v seized on September 15:th. Judging from echogram the trawl had then traversed an e bottom in depths between 5 000 and 5 metres. The catch contained 4 bottom fish 2 *Bathypterois* sp, 2 *Echinomacrurus mollis* a a number of bottom-living invertebrates.

Summarising the results from his trawli NYBELIN states, that 14 trawlings were car

, all at depths greater than 4 000 metres, which 10 gave catches of bottom animals. is means that 70 % of the hauls were cessful, as against 65 % for the trawlings earlier expeditions at corresponding depths. rthermore our expedition succeeded in trawl- at a greater depth than any earlier one, and reby in pushing down the hitherto known urrence of bottom animals by at least 1 600 tres.

th the »Albatross» to London and to Göteborg

A visit to London on our return voyage had en planned while the expedition was still in e Indian Ocean. The great help and encour- ement given me when planning the cruise by ding oceanographers in Britain, from the yal Society, at a meeting of which our plans d been described in a lecture prior to the ise, and by the Hydrographic Department the Admiralty, put us under an obligation to ke the »Albatross» to the city from which the nous »Challenger» cruise had been launched. e had in fact a special reason for wishing to so. All the attempts which had been made prolong the existence of the »Albatross» as a ep-sea research ship with her equipment act had failed. After the return of the expedi- n, she was to be reconverted into a combined ighter and training ship, and all her costly uipment was to be taken out of her and elved ashore. It was, therefore, the last portunity for showing this tool of research d the results gained with it to our British lleagues.

In Sweden this idea received generous support th from our benefactor Major H. JACOBSSON d from the owners of the ship Director T. CHRISTIANSSON, whose constant help ring the whole cruise had been invaluable to . In the spring of 1948 he approached the airman of the Port of London Authority, Sir HN ANDERSSON, who took a lively interest the proposed visit from the »Albatross» to

Fig. 117. The »Albatross» in London.

which he promised a distinguished berth in the Shadwell Docks. The energetic Director of the Swedish Institute in London for Anglo-Swedish cultural relations, Dr. ASTA KIHLBOM, had done all in her power to promote the plan. Various learned societies had declared their members to be interested in visiting the ship and seeing her equipment. Our arrival had been scheduled for September 23:d and we had inevitable misgivings, lest adverse winds and currents, which

Fig. 118. Nybelin showing his catch.

Fig. 119. Scanning the echograms.

are often encountered in approaching the English Channel, should unduly delay us.

Thanks to the excellent preparatory work done by the Swedish Institute and to the generous hospitality of the Port of London Authority, our visit to London was a great success. The six days we spent there were very busy indeed. More than two hundred distinguished representatives of the many sciences interested in deep-sea work came on board to view the ship, its laboratories, the big winch, KULLENBERG's piston corer and the WEIBULL plant for measuring the thickness of sediments by means of exploding depth-changes. In addition, NYBELIN and ERIKSSON demonstrated chosen specimens from the abyssal fauna which we had caught. JERLOV showed his optical methods for studying the sparsely distributed particles suspended in different-layers, while KOCZY rolled up our long echo-grams, showing the bottom profile over which we had been working.

Also the general public, which had been kept informed about our cruise through a series of articles published in »The Times», took a lively interest in the visit of the »Albatross». As it was obviously impossible to admit large crowds on board, we were invited instead to give radio talks on the expedition through the B. B. C. Even a television demonstration from Alexandra Palace was arranged, whe some of the rare organisms fro great depths were for the first tim shown by television. We receive the general impression that t »Albatross» cruise had stimulate great interest in the problems the ocean floor, and that the ne tools of research developed in Sw den will be used by future expe tions.

In the evening of September 29: the »Albatross» left London and s its course towards home wate Being myself obliged to prolong n stay in London for another day, travelled by air to Göteborg where I arriv three days before the »Albatross» and w thus able to board the ship at »Vinga» ligh house outside the harbour of Göteborg.

To say that our reception in our home po was warmhearted is an under-statement. W were honoured with music from the Nav Base, ships in the harbour were »dressed», sire were sounded and handkerchiefs were wav from everywhere ashore. The quay where landed held a throng of our relatives, frien and prominent citizens of Göteborg headed our chairman, Landshövding M. JACOBSSON

We had indeed been most lucky. All t members of the staff, the officers and the cr returned safe and sound. No serious illness h occurred on board and no life had been l

Fig. 120. Arrival in Göteborg.

reover our programme had, in the main, been ccessfully carried through. Some two hundred cious cores from the ocean floor, containing ique records of the deep, with a total length about one statute mile, were carefully pre-ved in the cool-storage room of the ship. ey represent material for many years of instaking laboratory work and measurements. r immediate duty was to carry this and other rts of our harvest to the Oceanographic stitute and the biological collections to the tural History Museum of Göteborg, where BELIN took charge of them.

The active work of the expedition was over. e much more lengthy, costly and laborious rk of applying the most efficient methods of dern science to the study of our collections s to commence.

The Harvest from the Ocean Depths

The »Albatross» Expedition was entirely a edish enterprise, planned in Sweden, carried t from a Swedish ship, using mainly a novel hnique worked out in Sweden, and financed Swedish donors. The material collected from e depths of three oceans, on the other hand, so vast that only by means of international -operation can it be completely worked up d analysed. In a dozen scientific institutions th in Europe and in the United States of nerica, samples from our long cores carefully osen and prepared, were analysed by eminent cialists in the different sciences involved. is whole-hearted co-operation from our colle-ues, both in Sweden and abroad, was one of our atest assets and a stimulus for our own work. The Oceanographic Institute of Göteborg, ere the expedition was planned and where st of the methods and instruments had been lved, served as a centre of organization, m which the samples were distributed and ere the results from the analyses were eived and tabulated. It has proved most ential, that the precious cores, the abstracts m the »records of the deep», which have been taken at such high costs in time, labour and money, should be carefully preserved against desiccation and mixing of layers from different levels. Unless properly cared for until they can be analysed by specialists, they may well prove »an embarrassment to their owner» as an English authority recently stated! On the other hand, if well preserved and judiciously sampled, they afford a wealth of information on the sediments covering the least accessible and least known part of the Earth's crust, the deep ocean floor, revealing its past history and the geochemical and geophysical transformations which have occurred within the carpet of deposit during millions of years.

Apart from the laborious and time-consuming descriptive, preparative and sampling work on the cores, the investigations in Göteborg have been mainly concentrated on the microchemical composition of the cores, on their content of radium and of its ancestor element uranium, the latter investigation having also been carried out in the Radium Institute of Vienna. Further, certain microfossils such as foraminifera and, especially, radiolarians have been studied in Göteborg. Specialists from Australia, Austria and France have been engaged on this work, together with members of the Swedish staff. Institutes in Stockholm and in Uppsala have undertaken geological, mineralogical and spectrographical analyses. In the laboratories at Kagghamra near Stockholm, Dr. G. ARRHENIUS geologist to the expedition, has done splendid work on the cores from the eastern Pacific Ocean and has opened new perspectives on the intricate problems of their stratigraphy. ARRHENIUS' work which has been printed in volume V of the Expedition Reports, has evoked very favourable comments from foreign authorities visiting Sweden. Together with his father, Dr. O. ARRHENIUS, he undertook the arduous task of analysing some 16 000 representative samples from all our cores for certain chemical elements of special interest.

On the European continent, Professor COR-

RENS of Göttingen, an acknowledged master of deep-sea sediment research, has had several of our most interesting cores from the equatorial part of the North Atlantic Ocean analysed by one of his pupils, Dr. LOCHER.

In Vienna analyses of the uranium and radium content in sea-water samples and in deep-sea deposits have been carried out under the direction of the chief of the Radium Institut, Professor BERTA KARLIK.

Besides the work in Stockholm and Göteborg, examination of the foraminiferal shells as indicators of past climatic changes has been carried out by Dr. W. SCHOTT of Hannover, by Prof. F. PHLEGER together with Miss F. PARKER and Miss J. PEIRSON of the Scripps Oceanographic Institut in La Jolla, California, and by Prof. JOHN WISEMAN of the British Museum in London.

One problem of special interest is the bottom temperature of the oceans during the Tertiary Age. From evidence obtained on land, the climate should then have been considerably warmer than during the succeeding Quaternary Age with its several glacial periods, so that ice-caps in the polar regions should have been either absent or of much less extent than at present. In such an event the present ice-cold temperature of the bottom water, mainly derived from the Antarctic, would not have prevailed during the Tertiary Age, and a higher temperature, similar to that at present found in the Mediterranean depths, should have dominated the ocean floor. Such a warm period, extending over millions of years, must have left its mark also on bottom organisms, which at that time were living in a temperature, perhaps ten degrees higher than at present. It remains for future research of the kind Arrhenius has started by his investigation of the long cores from the eastern Pacific, to confirm or to refute this hypotheses of a warm Tertiary period in the oceanic depths (C. EMILIANI, 1954).

The study of the cosmic components present in the deepest deposits, viz. the »cosmic spherules», may give information regarding the pas cosmic history of our planet, notably on varia tions in the bombardement by »bullets from th Cosmos», i. e. meteors and meteoritic dust.

WEIBULL's method for measuring the thick ness of the sediment carpet by means reflected echoes from exploding depth-charg has been perfected to such a degree, th reflecting surfaces in the sediment only metres apart can now be distinguished. Co bining such investigations with those made the »refraction method», when sound wav following a more horizontal path in the sed ment or in the substratum are recorded, o knowledge of the structure of both will increa considerably. Already it seems fairly certai through work carried out by EWING and othe that the bed-rock beneath the sediment carp is mainly basaltic in nature and thus differe from the granitic rocks predominating on lar The hidden topography of this oceanic bed-ro may be revealed by using WEIBULL's dept charges, preferably dropped from a helicop hovering near the surface of the sea.

Important results are being obtained throu JERLOV's analysis of his optical measureme made from the »Albatross». The extrem small suspended particles, revealed by intense Tyndall cone of light in samples tak from different depths, give information on water movements, both near the surface a at great depths. Also KOCZY's studies of water-layers immediately above the bott have thrown a new light on the little-kno interaction between the sediment and water in contact with it. Radium and urani analyses on sea-water and on the sedim layers in cores from great depths afford a ho ful although rather complicated approach their chronological problem and to the rat sedimentation. Also the mother element radium, ionium, has been made accessible measurements by E. PICCIOTTO and co-wor in Brussels.

Mineralogical studies of the rare stones sc

nes brought up from great depths by means a wide-bore coring-tube are also being carried t by O. MELLIS in Stockholm. They have ven conclusive evidence for the much-debated estion whether rocks and stones in great pths are liable to undergo a submarine eathering». Studies by the same author of e layers of volcanic ash in cores from the editerranean have already been mentioned, interesting also to the archaeologists.

Adding to these results from the analyses sea-water and of deep-sea deposits those om the biological work in the North Atlantic, w being published, one is justified in saying, at the Albatross brought back a rich harvest new and important observations from the ree oceans. When the study of this material s been completed and the results published r knowledge of the ocean floor will be con-derably increased.

The new technique of deep-sea research veloped in Sweden and elsewhere has thrown en a vast field of work in which specialists om half a score of different sciences can co-erate in solving hitherto unapproachable oblems in physical and chemical oceano-aphy, in the geophysics of the Earth's crust, submarine geology, in petrography and min-alogy, in geochemistry, paleontology, palaeo-matology and deep-sea biology, and where so the sciences of archaeology and of astro-my are involved. Undoubtedly the deep ean floor is now coming into the forefront as field for future research. Already two new ep-sea expeditions, the Danish with the »Galathea» and the British with the »Discovery II» have been sent out. For both these expeditions the techniques developed for the »Albatross» cruise have been applied. Moreover, the »Galathea» carried our big electric winch and other equipment, taken over from the »Albatross».

The field of work is so enormous that it calls for international co-operation in planning and for exchange of technical improvements and of results obtained. A step in this direction, taken by the Scandinavian countries, is the setting up of a joint committee for planning and carrying out deep-sea work with a special research ship equipped for the purpose. Such co-operation would make it possible to carry out investigations and analyse the material obtained without too large a financial strain on each of the participating countries.

At the beginning of this century, an international organization was started on Swedish initiative for the study of the waters round North-west Europe and of its important fishing grounds, the International Council for the Investigation of the Sea, with headquarters in Copenhagen; it has survived two world wars and is still active. The time now seems ripe for creating a similar co-operation in the study of the much vaster field of the deep ocean. Much greater efforts will be required than in shallow-water research. On the other hand, even more important results of pure scientific interest may be expected. In such co-operation Great Britain and the United States, the two greatest seafaring nations of the world, seem predestined to take leading parts.

Fig. 121. The Albatross medal.

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TABLE OF STATIONS

Station	Date	Ships-time from	Ships-time to	Position Lat.	Position Long.	Short core	Long core	Thick core	Trawling	Dredge	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth Coring stations	Echo depth Others
	1947																
1	13 July	0610	1820	N 45° 57′	W 7° 33′	0*)										4 780	
2	14 »	0707	1120	N 44° 22′	W 9° 13′						x						
3	14 »	1345	1400	N 44° 04′	W 9° 25′						x						
4	14 »	1555	1600	N 43° 48′	W 9° 29′						x						
5	17 »	1940	2005	N 40° 39′	W 9° 19′	x											
6	18 »	1420	1740	N 38° 32′	W 11° 46′	x					x						
7	19 »	2155	2213	N 34° 42′	W 14° 03′						x						
8	20 »	0510	1330	N 33° 44′	W 14° 19′						x						
9	20 »	2000	2015	N 33° 16′	W 15° 22′						x						
10	20 »	2055	2155	N 33° 14′	W 15° 30′						x		x				
11	24 »	1250	2225	N 32° 02′	W 19° 30′		x				x					4 004	
12	26 »	0935	1735	N 31° 27′	W 23° 19′		x				x					5 403	
13	26 »	2000	2105	N 31° 24′	W 23° 36′						x						
14	27 »	0915	0950	N 30° 46′	W 25° 15′								x				
15	27 »	1050	2140	N 30° 46′	W 25° 25′		x				x		x			5 464	
16	30 »	0745	1630	N 26° 25′	W 34° 00′	x	x				x	x				5 450	
17	31 »	0835	1520	N 25° 15′	W 36° 21′		x				x					5 640	
18	31 »	1635	1713	N 25° 07′	W 36° 20′						x						
19	1 Aug.	1050	1625	N 23° 58′	W 38° 56′		x				x					4 975	
20	2 »	1030	1705	N 22° 49′	W 41° 26′		x				x					5 945	
21	3 »			N 23° 00′	W 45° 10′						x						
22	4 »	1030	1305	N 21° 24′	W 46° 24′		x				x					3 180	
23	5 »	1040	1140	N 20° 01′	W 49° 18′		x				x					5 060	
24	6 »	1335	1810	N 18° 23′	W 52° 57′						x					5 550	
25	7 »	1710	1800	N 17° 03′	W 56° 18′						x						5 694
26	8 »	0710	1223	N 16° 21′	W 58° 15′						x						5 684
27	8 »	1405	1430	N 16° 14′	W 58° 29′						x						
28	12 »	1305	1820	N 14° 53′	W 61° 31′		x				x	x				2 665	2 724
29	13 »	1055	2010	N 14° 54′	W 63° 55′		x				x	x	x	x		2 627	2 646
30	14 »	0835	1430	N 14° 25′	W 65° 55′		x				x	x	x			4 900	4 942
31	14 »	1735	1745	N 14° 27′	W 66° 13′						x						
32	14 »	1905	2335	N 14° 25′	W 66° 26′						x	x					
33	15 »	0920	1810	N 14° 10′	W 68° 20′							x					5 105
34	16 »	0900	1135	N 14° 15′	W 70° 36′												3 630
35	16 »	1400	1805	N 14° 15′	W 71° 02′							x					
36	17 »	0905	0955	N 13° 40′	W 73° 26′						x						
37	17 »	1700	1800	N 13° 25′	W 74° 31′						x						
38	18 »	0910	1340	N 13° 05′	W 76° 56′						x	x					
39	19 »	0630	1600	N 11° 34′	W 78° 41′						x	x					3 556
40	19 »	1715	1735	N 11° 25′	W 78° 47′						x						3 544
41a	28 »	0740	1500	N 7° 14′	W 78° 50′				x								
41b	28 »	1620	1910	N 7° 04′	W 78° 52′				x								
42	28 »	1930	1945	N 7° 00′	W 78° 54′						x					3 000	2 792
43	29 »	1330	1600	N 6° 09′	W 80° 26′		x				x	x					3 120
44	29 »	2050	2110	N 5° 50′	W 80° 53′						x		x				
45	30 »	0725	1120	N 5° 15′	W 81° 42′						x	x				3 850	3 670
46	30 »	1950	2100	N 4° 41′	W 82° 25′						x		x				
47	1 Sept.	0720	1145	N 3° 05′	W 84° 39′							x				2 750	2 720
48	2 »	0940	1225	N 1° 45′	W 86° 14′						x	x					2 770
49	3 »	0845	1015	N 0° 33′	W 87° 50′							x					2 070
50	3 »	1240	1400	N 0° 30′	W 87° 46′												
51	3 »	2030	2210	N 0° 00′	W 88° 20′												
52	7 »	0620	1600	S 2° 52′	W 89° 50′		x				x	x				3 242	3 230
53	7 »	2010	2130	S 2° 48′	W 90° 25′								x				
54	8 »	1005	1025	S 2° 52′	W 92° 15′						x						

*) where coresampling was attempted but failed only a O is inserted.

ation	Date	Ships-time from	Ships-time to	Position Lat.	Position Long.	Short core	Long core	Thick core	Trawling	Dredge	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth Coring stations	Echo depth Others
55	8 Sept.	1300	2030	S 2° 44′	W 92° 45′	x	x				x	x				3 617	3 660
56	9 »	1000	1010	S 1° 33′	W 92° 19′						x						
57	9 »	1125	1300	S 1° 27′	W 92° 14′	x											
58	11 »	0940	1730	N 1° 04′	W 93° 20′	x	x				x	x				2 827	2 800
59	12 »	0915	1425	N 2° 10′	W 95° 30′						x	x					2 510
60	13 »	0855	1015	N 3° 18′	W 97° 44′							x					3 320
61	13 »	1130	1600	N 3° 20′	W 97° 53′	x	x				x					3 404	3 375
62	14 »	1050	1225	N 4° 32′	W 100° 06′						x	x					3 300
63	15 »	0800	1515	N 5° 42′	W 101° 41′	x	x				x	x				3 190	3 190
64	16 »	0735	1155	N 6° 18′	W 103° 35′												
65	16-17	1310	0020	N 6° 21′	W 103° 42′		x				x	x				3 470	3 430
66	17 »	1010	1310	N 6° 55′	W 104° 46′		x				x					3 565	3 526
67	18 »	0640	0805	N 7° 38′	W 106° 17′						x	x					3 750
68	18 »	0835	1510	N 7° 40′	W 106° 21′		x									3 725	3 742
69	19 »	0715	1140	N 8° 22′	W 108° 00′		x				x	x				3 800	3 800
70	20 »	0720	1200	N 9° 14′	W 109° 39′		x					x				3 567	3 690—3 860
71	20 »	1550	1600	N 9° 26′	W 109° 55′						x						
72	21 »	1420	1600	N 10° 35′	W 112° 05′						x	x					3 760
73	22 »	0720	1050	N 11° 25′	W 113° 48′		x				x					4 090	
74	22 »	1530	1845	N 11° 39′	W 114° 15′							x					4 150
75	23 »	0720	0845	N 12° 18′	W 115° 33′						x					4 240	4 244
76	24 »	0905	1250	N 13° 20′	W 117° 58′	x					x	x					4 290
77	25 »	0920	1055	N 14° 13′	W 120° 25′						x	x					4 370
78	26 »	1300	1720	N 15° 40′	W 123° 21′		x				x	x				4 300	4 300
79	27 »	0730	1140	N 16° 35′	W 124° 48′		x					x				4 230	4 240
80	28 »	0855	1300	N 17° 46′	W 126° 51′						x	x					4 620
81	29 »	0730	1400	N 15° 34′	W 127° 11′											4 730	4 820
82	30 »	0910	1040	N 13° 19′	W 127° 25′						x	x					4 730
83	30 »	1105	1440	N 13° 17′	W 127° 25′		x									4 803	4 809
84	30 »	2050	2245	N 12° 32′	W 127° 28′												4 730
85	1 Oct.	0730	1200	N 11° 30′	W 127° 37′	x	x				x	x				4 916	4 890
86	2 »	0705	1320	N 9° 50′	W 128° 13′	x	x				x	x				4 629	4 610
87	3 »	0710	1520	N 8° 25′	W 128° 48′	x	x				x	x				4 607	4 720
88	4 »	0705	1150	N 6° 44′	W 129° 28′	x	x				x	x				4 440	4 350
89	5 »	1020	1150	N 4° 49′	W 130° 52′						x	x					
90	6 »	0850	1450	N 3° 05′	W 133° 06′	x	x				x	x				4 338	4 320
91	7 »	0550	0715	N 1° 49′	W 134° 45′		x				x	x					4 590
92	7 »	0930	1305	N 1° 35′	W 134° 57′	x	x				x					4 540	
93	8 »	0330	1140	S 0° 06′	W 135° 58′	x	x				x	x				4 475	4 440
94	9 »	0935	1515	S 3° 00′	W 136° 26′	x	x				x	x				4 511	4 460
95	10 »	1100	1445	S 5° 37′	W 137° 53′	x	x				x					4 610	4 614
96	20 »	1135	1210	S 11° 51′	W 144° 03′												
97	20 »	1410	1807	S 12° 00′	W 144° 20′		x				x					5 008	4 993
98	21 »	1120	1610	S 13° 03′	W 146° 01′		x							x		5 055	5 054
99	22 »	0720	1240	S 14° 12′	W 147° 37′		x				x			x		3 925	3 925
100	23 »	0705	1000	S 15° 49′	W 148° 53′		x				x					4 290	4 330
101	23 »	1140	1830	S 15° 57′	W 148° 57′	x							x	x			
102	5-6 Nov.	1315	2240	S 13° 25′	W 149° 30′	x	x x		x		x x	x				4 630	4 630
103	7-8 »	2130	1145	S 11° 20′	W 150° 30′				x								
104	8 »	1320	1650	S 11° 15′	W 150° 30′		x				x	.				4 900	4 932
105	10 »	0755	1810	S 7° 38′	W 152° 53′	x x	x x				x	x				5 015	4 990
106	12 »	0845	1215	S 4° 04′	W 152° 53′	x	x				x					5 200	5 209
107	12 »	2035	2100	S 3° 21′	W 152° 36′								x				
108	13 »	0930	1350	S 2° 01′	W 152° 16′							x		x			4 750
109	14 »	0720	1040	S 0° 29′	W 151° 33′	x	x									4 575	4 548
110	14 »	1310	1810	S 0° 20′	W 151° 31′						x				x		

Station	Date	Ships-time from	Ships-time to	Position Lat.	Position Long.	Short core	Long core	Thick core	Trawling	Dredge	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth Coring stations	Echo depth Others
111	15 Nov.	0045	0400	N 0° 02′	W 151° 07′							x	x				2 490
112	15 »	1000	1500	N 0° 20′	W 150° 36′	x	x				x					4 400	4 386
113	16 »	2120	2250	N 2° 06′	W 149° 49′							x					4 540
114	17 »	1300	1825	N 3° 45′	W 149° 44′	x	x				x					5 155	4 966
115	17 »	2130	2235	N 4° 04′	W 149° 42′							x					
116	18 »	1305	1420	N 5° 47′	W 149° 42′							x					
117	19 »	2130	2200	N 7° 56′	W 149° 13′								x				
118	20 »	0910	0925	N 8° 17′	W 148° 41′						x						
119	21 »	2210	2335	N 8° 43′	W 148° 36′							x					5 220
120	22 »	0900	1220	N 9° 30′	W 148° 40′	x	x									5 384	5 373
121	23 »	0830	0950	N 11° 25′	W 149° 33′							x					
122	24 »	0815	1415	N 13° 24′	W 151° 12′	x	x					x				5 560	5 520
123	25 »	1300	1915	N 15° 14′	W 152° 49′							x	x				5 750
124	15 Dec.	1450	1700	N 18° 25′	W 160° 16′	x	x									5 293	
125	16 »	1320	1730	N 16° 19′	W 162° 57′	x	x									5 650	5 623
126	17 »	0910	1050	N 14° 39′	W 164° 50′							x					5 480—5 53
127	17 »	1330	1715	N 14° 28′	W 164° 59′	x	x				x					5 460	5 468
128	18 »	1300	2110	N 12° 16′	W 166° 48′		x				x	x				5 080	5 380
129	19 »	1545	1712	N 10° 10′	W 168° 02′						x	x					5 310
130	20 »	0705	1200	N 8° 40′	W 169° 28′	x	x				x	x				5 456	5 450
131	21–22 »	1325	0200	N 6° 21′	W 171° 52′	x	x				x	x				5 725	5 780
132	22 »	1025	1430	N 5° 34′	W 172° 12′	x	x				x					5 590	
133	22 »	1905	2330	N 5° 00′	W 172° 21′							x					5 390—5 46
134	23 »	0940	1400	N 4° 02′	W 172° 19′	x	x				x					5 560	
135	24 »	0105	0225	N 2° 54′	W 173° 17′							x					5 580
136	24 »	0700	1052	N 2° 23′	W 173° 50′	x	x				x					5 560	5 579
137		1325	1510	N 0° 00′	W 176° 32′												5 630
138	26–27 »	1015	0225	S 2° 37′	W 177° 45′	x	x				x	x				5 770	5 670—5 82
139	27 »	1000	1330	S 2° 48′	W 178° 57′	x	x				x					5 465	5 462
140	30 »	1320	1650	S 3° 21′	E 174° 12′	x		x			x					4 830	4 727
141	31 »	1300	1605	S 2° 50′	E 171° 18′	x	x				x			x		4 096	4 096
	1948																
142	2 Jan.	0700	1410	S 1° 20′	E 167° 23′	x x	x				x			x		3 942	3 970
143	3 »	1030	1830	S 0° 09′	E 165° 26′						x	x			x		4 450
144	5 »	0920	1225	N 0° 34′	E 159° 59′	x	x				x					2 868	2 882
145	6 »	0810	1015	N 0° 52′	E 157° 04′	x	x				x					2 194	
146	7 »	1120	1350	N 0° 48′	E 154° 46′	x	x									3 030	
147	7–8 »			Kapingamarangi										x			
148	9 »	1020	1315	N 1° 40′	E 152° 37′	x	x				x					3 670	
149	11 »	1320	1805	N 2° 16′	E 148° 45′	x	x				x					6 080	
150	12 »	1330	2010	N 2° 09′	E 146° 52′	x	x				x	x				4 525	4 590
151	13 »	0715	1100	N 2° 11′	E 145° 47′	x	x				x			x		4 100	
152	13 »	1300	1705	N 2° 13′	E 145° 35′										x		
153	14 »	1305	1610	N 2° 25′	E 144° 04′	x	x				x					4 525	
154	15 »	1300	1550	N 2° 36′	E 142° 32′			x			x					3 713	
155	17 »	0835	1140	N 2° 38′	E 139° 34′	x	x				x					4 275	
156	19 »	0725	1100	N 2° 44′	E 134° 58′	x	x							x		4 240	
157	19 »	1350	1720	N 2° 51′	E 134° 37′							x					
158	21 »	0930	1240	N 4° 25′	E 130° 40′	x	x									4 460	
159	21 »	1630	1700	N 4° 26′	E 130° 21′						x						
160	22 »	1220	1800	N 4° 43′	E 128° 07′	x	x				x			x		7 785	
161	23 »	0005	1030	N 5° 10′	E 127° 53′							x					
162	23–24 »	1330	1525	N 5° 23′	E 127° 48′	x	x				x	x				8 390	9 090—9 2
163	24 »	1620	1650	N 5° 23′	E 127° 46′						x						
164	24 »	1730	1755	N 5° 23′	E 127° 46′						x						
165	29 »	1105	1210	N 0° 59′	E 127° 00′									x			

on	Date	Ships-time from	Ships-time to	Position Lat.	Position Long.	Short core	Long core	Thick core	Trawling	Dredge	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth Coring stations	Echo depth Others
6	29 Jan.	1345	1600	N 1° 01′	E 126° 56′			x								3 190	
7	29 »	1630	1800	N 1° 00′	E 126° 54′			x								2 685	
8	30 »	0945	1150	S 1° 09′	E 126° 22′			x								2 417	
9	31 »	0545	1820	S 2° 44′	E 125° 22′										x	5 325	
0	1 Febr.	1530	1605	S 4° 48′	E 123° 49′						x						
1	2 »	1545	1825	S 7° 00′	E 123° 04′		x				x					2 960	
2	3 »	1440	1735	S 7° 58′	E 121° 45′		x				x					4 375	
3	4 »	0845	1450	S 7° 45′	E 120° 30′							x					5 020
4	4 »	1625	1700	S 7° 46′	E 120° 20′						x						
5	5 »	0655	1800	S 7° 48′	E 119° 01′		x								x	4 585	
6	6 »	0900	1040	S 7° 51′	E 117° 32′		x									1 300	
7	6 »	1410	1515	S 7° 54′	E 117° 07′										x		
8	7 »	0700	0800	S 7° 46′	E 115° 11′		x									970	
9	7 »	1335	1420	S 7° 33′	E 114° 25′	x	x							x		114	
0	15 »	1245	1330	S 7° 24′	E 113° 10′									x			
1	15 »	1710	1750	S 7° 30′	E 113° 38′	x	x									68	
2	23 »	1010	1300	S 10° 15′	E 111° 53′	x	x									3 805	3 789
3	24 »	0845	1520	S 10° 19′	E 109° 40′		x					x				6 410	5 883
4	24–25 »	1900	0030	S 10° 12′	E 109° 41′							x					
5	25 »	0900	1410	S 10° 07′	E 108° 56′		x				x					6 875	6 864
6	26 »	1235	1655	S 10° 46′	E 106° 16′	x	x				x					5 735	5 744
7	27 »	1100	1135	S 11° 03′	E 103° 49′									x			
8	27 »	1300	1640	S 11° 07′	E 103° 39′	x	x									5 735	5 803
9	28 »	0815	1130	S 11° 28′	E 102° 24′	x	x									5 225	5 192
0	28 »	1330	2340	S 11° 28′	E 102° 14′						x						5 085
1	29 »	0745	0805	S 11° 25′	E 102° 13′									x			
2	29 »	1050	1210	S 11° 25′	E 102° 08′									x			
3	29 »	1550	1615	S 11° 25′	E 101° 39′									x			
4	1 March	0730	1120	S 11° 22′	E 99° 41′	x	x				x					5 440	5 423
5	2 »	0700	1000	S 11° 10′	E 96° 42′	x	x									4 423	4 432
6	2 »	1325	1750	S 11° 10′	E 96° 15′							x					4 506
7	2 »	1855	1945	S 11° 11′	E 96° 07′						x						
8	3 »	0830	1515	S 11° 30′	E 94° 06′	x	x									5 280	5 271
9	4 »	0925	1325	S 11° 33′	E 91° 26′	x		x			x					5 200	5 185
0	5 »	0955	1235	S 11° 01′	E 88° 26′							x					2 258
1	6 »	1150	1215	S 8° 49′	E 88° 16′									x			
2	6 »	1525	1635	S 8° 26′	E 88° 16′							x					
3	7 »	1010	1430	S 6° 24′	E 88° 45′												
4	7 »	1430	1910	S 6° 26′	E 88° 53′							x					3 750
5	8 »	0950	1700	S 4° 47′	E 88° 18′		x				x	x				5 050	4 999
6	9 »	1045	1810	S 2° 33′	E 88° 19′	x x	x x					x		x		4 840	4 820
7	10–11 »	1350	0105	S 0° 00′	E 88° 18′							x					4 486
8	11 »	1555	2100	N 1° 56′	E 88° 12′		x				x	x				4 300	4 290
9	12 »	0810	1520	N 2° 45′	E 86° 53′		x				x					4 276	4 303
0	13 »	0925	1530	N 3° 49′	E 84° 46′			x			x					4 186	4 192
1	14 »	0900	1430	N 4° 36′	E 82° 36′							x					4 133
2	15 »	0955	1255	N 5° 12′	E 80° 20′			x								4 249	4 246
3	28 »	1325	1645	N 4° 12′	E 77° 28′							x					3 120
4	29 »	1420	1820	N 2° 18′	E 76° 02′		x				x					3 765	3 770
5	30 »	1445	1745	N 0° 35′	E 75° 14′		x									4 048	4 032
6	30–31 »	2320	0405	N 0° 04′	E 74° 53′						x	x					4 268—4 286
7	31 »	1130	1320	S 0° 31′	E 74° 33′		x									3 285	3 336
8	31 »	1935	1955	S 0° 57′	E 73° 56′						x						
9	1 Apr.	1315	1725	S 1° 12′	E 72° 00′		x				x					4 417	4 424
0	2 »	0850	1240	S 1° 22′	E 70° 28′							x		x			3 885
1	3 »	1040	1330	S 1° 20′	E 68° 20′		x				x					3 620	3 625
2	3 »	1525	1708	S 1° 20′	E 68° 12′	x											

Station	Date	Ships-time from	Ships-time to	Position Lat.	Position Long.	Short core	Long core	Thick core	Trawling	Dredge	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth Coring stations	Echo depth Others
223	4 Apr.	1015	1715	S 1° 19′	E 66° 16′	x	x				x	x				4 380	4 344
224	5 »	1355	1725	S 1° 20′	E 64° 00′	x	x				x					4 405	
225	6 »	0745	1735	S 1° 22′	E 62° 38′	x	x				x	x				4 750	4 658
226	7 »	0800	1135	S 1° 37′	E 61° 00′	x	x				x					4 643	4 616
227	8 »	0730	1330	S 2° 13′	E 58° 43′	x	x				x	x		x		4 370	4 368
228	9 »	0910	1430	S 3° 18′	E 56° 47′	x	x				x	x				4 082	4 016
229	16 »	0920	1025	S 2° 48′	E 55° 35′						x						
230	16 »	1410	1735	S 2° 18′	E 55° 33′	x	x				x					4 357	4 366
231	17 »	1050	1415	S 0° 23′	E 54° 30′	x	x				x					4 855	4 862
232	17 »	1755	2300	S 0° 01′	E 54° 16′							x					4 622
233	18 »	1925	1955	N 2° 22′	E 53° 09′						x						
234	19 »	1050	1430	N 4° 28′	E 52° 48′	x	x				x					5 130	5 126
235	20–21 »	0930	0235	N 7° 14′	E 52° 49′	x	x					x				5 130	5 073
236	21 »	0845	1215	N 7° 55′	E 52° 58′												
237	21 »	1340	1645	N 8° 05′	E 53° 03′	x	x									5 120	5 096
238	21 »	2115	2140	N 8° 40′	E 52° 52′						x						
239	22 »	0850	1230	N 10° 06′	E 52° 45′	x	x				x					4 168	4 155
240	22–23 »	1450	0610	N 10° 23′	E 52° 22′							x			x		3 793
241	24 »	0920	1035	N 12° 53′	E 49° 31′	x											
242	24 »	1430	1530	N 12° 48′	E 49° 00′	x											
243	24 »	1905	2215	N 12° 45′	E 48° 26′							x					2 540
244	25–26 »	2205	0015	N 12° 10′	E 45° 17′							x					911
245	26 »	0850	1045	N 11° 57′	E 44° 18′	x	x									883	882
246	26 »	2110	2225	N 12° 33′	E 43° 20′							x					330
247	27 »	0640	0740	N 13° 30′	E 42° 48′							x					190
248	27 »	1600	1800	N 14° 12′	E 42° 18′	x	x					x				300	355
249	28 »	1430	1700	N 16° 05′	E 41° 27′	x	x									1 748	1 670
250	29 »	0740	0940	N 17° 24′	E 40° 17′	x	x									1 158	1 124
251	29 »	1040	1120	N 17° 29′	E 40° 22′							x		x			
252	29 »	1515	1655	N 17° 56′	E 39° 57′	x	x									1 280	1 251
253	3 May	0845	1215	N 21° 09′	E 38° 07′	x						x					2 176
254	3 »	1335	1555	N 21° 18′	E 38° 09′							x					1 937
255	3 »	1615	1810	N 21° 20′	E 38° 09′		x									1 864	1 820
256	4 »	1045	1150	N 23° 15′	E 37° 24′	x	x									860	849
257	5 »	0840	0900	N 24° 30′	E 36° 16′	x											1 069
258	5 »	1430	1450	N 24° 58′	E 35° 55′	x											724
259	6 »	0720	0750	N 26° 09′	E 35° 10′	x											
260	6 »	1310	1335	N 26° 27′	E 34° 52′	x											937
261	15 »	0300	0450	N 31° 25′	E 32° 25′	x	x					x				30	29
262	15 »	0644	0728	N 31° 41′	E 32° 30′	x						x					49
263	15 »	0840	1025	N 31° 51′	E 32° 34′	x	x					x				381	381
264	15 »	1300	1345	N 31° 48′	E 32° 06′	x											
265	15 »	1450	1535	N 31° 59′	E 32° 06′	x	x									230	249
266	16 »	0300	0345	N 31° 37′	E 30° 23′	x						x					23
267	16 »	0415	0422	N 31° 41′	E 30° 22′							x					33
268	16 »	0512	0528	N 31° 45′	E 30° 21′							x					52
269	16 »	0605	0633	N 31° 49′	E 30° 20′	x						x					57
270	16 »	0700	0728	N 31° 53′	E 30° 19′	x						x					106
271	16 »	0755	0845	N 31° 56′	E 30° 17′							x					214
272	16 »	1035	1215	N 32° 12′	E 30° 13′	x	x					x		x		1 176	82
273	16 »	1700	1930	N 32° 47′	E 30° 33′		x									2 062	2 091
274	17 »	0530	0725	N 33° 59′	E 31° 02′		x									2 500	2 524
275	17 »	1600	1735	N 33° 55′	E 30° 17′		x									2 810	2 843
276	18 »	0730	0845	N 33° 54′	E 28° 29′		x									2 664	2 697
277	18 »	1010	1345	N 33° 54′	E 28° 17′										x		
278	19 »	0500	0640	N 33° 54′	E 26° 10′		x									2 900	2 890
279	19 »	1050	1300	N 34° 24′	E 26° 11′		x									3 635	3 601
280	19 »	1600	1730	N 34° 36′	E 25° 59′		x									2 680	2 644

tion	Date	Ships-time from	Ships-time to	Position Lat.	Position Long.	Short core	Long core	Thick core	Trawling	Dredge	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth Coring stations	Echo depth Others
81	20 May	0630	0755	N 34° 12′	E 24° 22′		x									2 130	2 171
82	20 »	1030	1120	N 34° 24′	E 24° 00′									x			
83	20 »	1540	1720	N 34° 48′	E 23° 29′		x									3 000	2 993
84	21 »	0840	1205	N 35° 52′	E 21° 53′		x									3 665	3 648
85	21–22 »	1440	0145	N 35° 41′	E 21° 50′		x					x				4 270	4 240
86	22 »	0915	1100	N 35° 47′	E 20° 42′		x									2 940	2 922
87	23 »	0840	1455	N 36° 13′	E 17° 28′		x				x			x		3 555	3 544
88	24 »	0450	0640	N 37° 29′	E 15° 58′		x									2 370	2 354
89	24 »	0940	1130	N 37° 33′	E 15° 24′		x				x					2 050	2 040
90	25 »	1035	1230	N 39° 28′	E 13° 48′		x									3 070	3 058
91	25 »	1717	1735	N 40° 05′	E 13° 45′						x						
92	25 »	2005	2115	N 40° 30′	E 13° 43′	x											
93	26 »	0200	0330	N 40° 18′	E 12° 54′	x											
94	26 »	0830	1215	N 40° 12′	E 12° 21′	x								x			
95	26 »	1320	1700	N 40° 13′	E 12° 22′		x				x					3 610	3 614
96	28 »	1230	1430	N 43° 37′	E 7° 44′		x									1 890	1 872
97	3 June	1125	1515	N 43° 34′	E 7° 43′		x									2 230	2 226
98	5 »	1545	1745	N 42° 38′	E 7° 09′		x				x					2 665	2 668
99	5 »	2035	2115	N 42° 17′	E 6° 57′						x						
00	6 »	1600	1715	N 40° 05′	E 5° 34′						x						
01	7 »	0935	1440	N 38° 31′	E 3° 50′	x	x					x				2 595	2 570
02	7 »	1720	1815	N 38° 21′	E 3° 27′						x						
03	8 »	0940	1145	N 37° 26′	E 1° 05′		x				x					2 795	2 839
04	9 »	0950	1040	N 35° 57′	W 2° 02′						x						
05	9 »	1315	1525	N 35° 55′	W 2° 20′	x	x				x					1 325	1 329
06	10 »	2200	2320	N 36° 02′	W 4° 59′							x					882
07	12 »	1535	1635	N 35° 52′	W 5° 54′							x					497
08	12 »	2305	0020	N 35° 45′	W 6° 50′							x					770
09	13 »	0915	1125	N 34° 56′	W 7° 44′	x						x					1 510
10	13 »	1335	1430	N 34° 50′	W 8° 01′	x											2 313
11	14 »	1045	1425	N 33° 29′	W 11° 03′		x				x					4 390	4 391
12	16 »	0920	1430	N 29° 55′	W 17° 32′	x	x				x					4 320	4 341
13	16–17 »	1530	0440	N 29° 48′	W 17° 39′				x								4 306
13	16–17 »	1530	0440	N 30° 05′	W 17° 18′				x								4 276
14	17 »	0720	0945	N 29° 48′	W 17° 27′							x					4 258
15	18 »	0900	1340	N 27° 27′	W 19° 43′	x	x				x					4 362	4 368
16	19 »	0925	1445	N 25° 29′	W 21° 37′	x	x				x					4 675	4 674
17	19 »	1700	2120	N 25° 15′	W 21° 47′				x								
18	20 »	1500	1855	N 23° 13′	W 23° 01′		x				x					4 880	4 886
19	21–22 »	0610	0245	N 22° 31′	W 23° 28′	x	x		x		x	x				4 936	4 908
20	23 »	0700	1115	N 20° 21′	W 20° 37′	x	x				x					3 820	3 828
21	24 »	0530	0935	N 18° 50′	W 18° 24′	x	x					x				2 810	290
22	24 »	1225	1610	N 18° 44′	W 18° 44′	x	x					x				2 973	2 970
23	25 »	0615	1130	N 17° 57′	W 21° 03′	x	x				x	x				3 100	3 065
24	26 »	0845	1045	N 16° 56′	W 23° 56′		x									3 450	3 448
25	30 »	1040	1805	N 15° 53′	W 25° 27′	x	x					x				4 280	4 280
26	1 July	1420	1745	N 13° 37′	W 25° 55′	x	x					x				4 810	4 810
27	2 »	1310	1400	N 11° 12′	W 26° 24′							x					5 650
28	2–3 »	2250	0910	N 10° 12′	W 26° 36′	x	x					x				5 500	5 358
29	3–4 »	1600	0550	N 9° 38′	W 26° 20′				x								
29	3–4 »	1600	0550	N 9° 50′	W 26° 30′				x								
30	5 »	0840	1610	N 7° 53′	W 24° 43′	x	x				x	x				4 975	4 940
31	6 »	1145	1630	N 7° 13′	W 22° 38′	x	x									4 125	4 136
32	7 »	0845	1630	N 5° 45′	W 21° 43′	x	x				x	x				3 579	3 545
33	8 »	2300	2350	N 3° 38′	W 20° 32′							x					4 330
34	9 »	0630	1120	N 3° 12′	W 20° 38′	x	x				x					4 560	4 580
35	10 »	0530	1620	N 2° 06′	W 20° 07′	x	x				x	x			x	5 065	5 060
36	11 »	1600	1712	N 0° 45′	W 18° 52′						x	x					5 030

Station	Date	Ships-time		Position		Short core	Long core	Thick core	Trawling	Dredg	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth	
		form	to	Lat.	Long.											Coring station	Others
337	12 July	0945	1345	S 0° 03′	W 18° 13′							x					6 030
338	13 »	0705	0955	S 0° 08′	W 18° 11′	x								x			
339	13 »	1350	1930	S 0° 07′	W 18° 12′		x				x					7 316	7 278
340	14–15 »	0515	0345	S 0° 13′	W 18° 26′	x	x					x	x			7 599	7 594
341	15 »	1230	1510	S 0° 17′	W 18° 24′				x								
341	15 »	1230	1510	S 0° 17′	W 18° 21′				x								
342	16 »	0110	2325	N 1° 11′	W 18° 48′	x			x			x					5 261
342	16 »	0110	2325	N 0° 54′	W 18° 33′	x			x			x					
343	17 »	0900	1600	N 1° 10′	W 19° 50′	x	x				x	x				4 345	4 301
344	18 »	1310	1600	N 0° 44′	W 22° 48′							x					3 813
344	18 »	1310	1600	S 0° 14′	W 18° 26′							x					
345	19 »	0940	1525	N 0° 30′	W 25° 38′	x	x				x	x				3 620	3 265
346	19–20 »	2345	0535	N 0° 20′	W 26° 57′				x								
346	19–20 »	2345	0535	N 0° 19′	W 26° 48′												
347	20 »	1240	1910	N 0° 27′	W 27° 45′	x	x				x	x				3 740	3 696
348	21 »	0750	1230	N 0° 59′	W 29° 22′	x											1 300
348	21 »	0750	1230	N 0° 57′	W 29° 22′	x											783
349	21 »	1535	1725	N 0° 57′	W 29° 49′							x					2 820
350	22 »	0635	1015	N 0° 48′	W 31° 28′	x	x									3 209	3 217
351	22 »	1605	1840	N 0° 39′	W 32° 10′						x	x					3 858
352	23 »	0555	0730	N 0° 15′	W 33° 37′	x											
353	23–24 »	0820	1355	N 0° 16′	W 33° 40′		x		x		x	x					4 547
353	23–24 »	1450	0345	N 0° 16′	W 33° 40′		x		x		x	x				4 580	4 590
354	24 »	1325	1740	N 0° 06′	W 34° 41′		x				x	x				4 568	4 550
355	25 »	1150	1600	N 0° 37′	W 37° 06′	x	x									4 539	4 538
356	26 »	1020	1520	N 2° 10′	W 39° 06′	x	x				x					4 483	4 484
357	26–27 »	1840	1125	N 2° 26′	W 39° 26′				x			x					4 436
357	26–27 »	1840	1125	N 2° 24′	W 39° 12′				x			x					
358	28 »	0915	1210	N 4° 26′	W 41° 47′	x										4 353	4 328
359	29 »	0730	1740	N 6° 17′	W 43° 20′	x	x				x				x	4 534	4 531
360	30 »	0930	1640	N 7° 29′	W 45° 01′	x	x					x				4 470	4 430
361	31 »	0830	1355	N 8° 15′	W 46° 30′	x	x							x		4 570	4 556
362	2–3 Aug.	0700	0030	N 11° 45′	W 51° 29′	x			x		x	x					4 974
362	2–3 »	0700	0030	N 11° 44′	W 51° 09′	x			x		x	x					
363	3–4 »	0910	0040	N 12° 22′	W 52° 00′	x			x								
363	3–4 »	0910	0040	N 12° 13′	W 51° 54′	x			x								
364	4 »	1030	1610	N 12° 54′	W 52° 55′	x	x				x					5 128	5 148
365	5 »	0900	1635	N 14° 32′	W 55° 55′	x	x				x			x		5 475	5 774
366	6 »	0705	1955	N 15° 44′	W 56° 50′	x	x x	x			x					5 320	5 317
367	7 »	0900	1735	N 16° 51′	W 58° 21′	x	x				x	x				5 832	5 655
368	9 »	0645	1305	N 19° 04′	W 63° 02′	x	x							x		5 953	5 959
369	10 »	0735	1025	N 17° 47′	W 65° 14′	x	x									2 105	2 092
370	17–18 »	1830	1420	N 19° 49′	W 65° 01′				x								
370	17–18 »	1830	1420	N 19° 40′	W 65° 05′				x								
371	20–21 »	0945	0830	N 24° 12′	W 63° 23′	x			x			x	x				5 615
371	20–21 »	0945	0830	N 24° 26′	W 63° 28′	x			x			x	x				
372	21 »	1015	1110	N 24° 32′	W 63° 19′									x			
373	23–25 »	1805	0130	N 28° 25′	W 61° 05′	x				x	x	x		x			5 917
373	23–25 »	1805	0130	N 28° 05′	W 60° 49′	x				x	x	x		x			
374	25 »	0830	1815	N 28° 33′	W 59° 49′	x	x							x		6 310	6 258
375	26 »	0810	1530	N 29° 21′	W 58° 09′	x	x							x		5 450– 5 920	5 356
376	27–28 »	0915	0935	N 30° 29′	W 56° 07′	x	x		x		x			x		5 617	
376	27–28 »	0915	0935	N 30° 30′	W 56° 19′	x	x		x		x			x			5 586
377	28 »	1130	1240	N 30° 38′	W 56° 05′									x			
378	28 »	1430	1945	N 30° 46′	W 55° 56′			x								5 605	5 611
379	30 »	0655	1740	N 33° 10′	W 50° 53′	x	x								x	4 852	4 847

ion	Date	Ships-time		Position		Short core	Long core	Thick core	Dredge	Trawling	Explosions	Hydrogr.	Transp.	Light	Geotherm.	Echo depth	
		from	to	Lat.	Long.											Coring station	Others
30	31 Aug.	0910	1430	N 33° 16′	W 49° 00′	x	x									5 520	5 410
31	1 Sept.	1100	1655	N 34° 06′	W 46° 12′	x	x				x					4 663	4 645
32	2 »	0545	1105	N 34° 57′	W 44° 16′	x	x				x					4 286	4 287
33	2 »	1220	1645	N 34° 54′	W 44° 20′	x	x									4 292	4 302
34	3 »	0735	2245	N 36° 25′	W 43° 01′					x		x					4 694
35	4 »	1405	1910	N 37° 37′	W 41° 41′	x		x			x					4 940	4 939
36	6 »	0900	1405	N 40° 32′	W 38° 17′	x	x				x					4 257	4 273
37	7–8 »	0930	0335	N 40° 34′	W 35° 52′	x				x		x					4 521
38	8 »	0845	1305	N 40° 40′	W 34° 58′	x		x			x					4 060	4 066
39	9 »	0700	0800	N 41° 09′	W 32° 08′	x											2 874
90	9 »	0955	1255	N 41° 08′	W 31° 50′	x	x				x					2 684	2 682
91	9 »	1515	1800	N 41° 12′	W 31° 30′	x	x									2 640	2 648
92	10 »	0710	0945	N 41° 35′	W 29° 37′	x	x									1 995	2 001
93	10 »	1530	1630	N 41° 44′	W 28° 44′	x											2 512
94	11 »	0620	0930	N 42° 16′	W 26° 36′	x	x									3 216	3 224
95	11 »	1300	1500	N 42° 23′	W 26° 02′		x									3 485	3 479
96	12 »	0535	0645	N 41° 04′	W 24° 16′	x											3 747
97	12 »	1735	1900	N 41° 37′	W 23° 01′	x											4 153
98	13 »	0830	1055	N 42° 27′	W 21° 08′		x									3 760	3 738
99	13 »	1255	1312	N 42° 35′	W 20° 57′									x			
00	13–14 »	2215	1810	N 43° 04′	W 19° 40′	x	x				x	x				5 980	5 990
01	15 »	0120	1340	N 43° 40′	W 18° 45′					x	x						
01	15 »	0120	1340	N 43° 24′	W 18° 59′					x	x						
02	18 »	0955	1300	N 47° 41′	W 12° 43′			x			x					4 288	4 293
03	18 »	2025	2040	N 48° 00′	W 11° 59′						x						